Trends in Fish Populations of Suisun Marsh
January 2001 - December 2001

Annual Report For:
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Attention: Heidi Rooks

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Introduction

Suisun Marsh is the largest brackish water tidal marsh on the West Coast of the United States. It is located in the center of the San Francisco Estuary, adjacent to Suisun Bay (Figure 1.1). Suisun Marsh is important to fish in the estuary because it contains many kilometers of productive tidal sloughs inhabited by numerous estuarine-dependent fish species, both native and alien. The native estuarine species have generally declined, some to the point that they have protection under the U.S. Endangered Species Act of 1973 (Sacramento splittail, delta smelt, and chinook salmon). Numerous factors have contributed to the decline of fish in the estuary including habitat alteration, water diversions and impacts associated with the continued increase in the number and abundance of introduced species. The UC Davis Suisun Marsh fish study was initiated in 1979 by P. B. Moyle as a way to monitor the fish populations, especially in response to modifications being made affecting the way water moves through the marsh. From the beginning, the study has been focused on the entire assemblage of fishes in the marsh examining such factors as changes in species abundance and composition through time, use of the various habitats within the marsh, and association of changes in the fish assemblages with natural and anthropogenic changes. There are currently two major components to the Suisun Marsh fish study, including a juvenile and adult sampling component and a larval fish sampling component. The larval fish sampling component was initiated in 1994 to gain a better understanding of larval fish use of Suisun Marsh. Moyle *et al.* (1986) summarized the first five years of the Suisun Marsh juvenile and adult fish data set and found strong seasonal trends in abundance and occurrence of species as well as co-occurring groups of species. They noticed a downward trend in total catch but considered the results inconclusive due to limited data. Meng *et al.* (1994) summarized the data through 1992 and found the Suisun Marsh fish assemblage to be much less predictable than had been concluded in the 1986 paper. They recorded strong downward trends in most fish populations and discussed the recent invasions of the shimofuri goby and the Asian clam, *Potamocorbula amurenis*. These trends continued through 1999, as reported in Matern et al. (2002). Recent publications (Matern et al. 2002; Meng and Matern 2001) and annual reports to the California Department of Water Resources (Matern and Moyle 1994, Matern *et al.* 1995, 1996, 1997, 1998, Schroeter and Moyle 1999 and 2000) further documented overall declines in juveniles and adults of most fish populations and have presented possible factors contributing to successful spawning and rearing of larval fishes within Suisun Marsh. Over its duration, the Suisun Marsh fish project has significantly improved our understanding of species use of brackish water tidal habitat and has contributed to the successful management of protected species in the system by; (1) documenting population fluctuations in association with changing environmental and biotic conditions, (2) improving our understanding of larval, juvenile, and adult fish use patterns, and (3) monitoring species changes over time.

Continued declines in native fish abundance, increases in the number and abundance of introduced species, and a limited understanding of larval fish occurrence and use of Suisun Marsh have prompted further investigation. This report presents the findings from the 2001 fish sampling season.

Part 1 of this report summarizes and compares fish catch data from the 2001 juvenile and adult survey with earlier collection data. Part 2 summarizes results from the 2001 larval fish survey.

Study area:

Suisun Marsh (Figure 1.1) is a large tidal marsh (approximately 34,000 ha) at the downstream end of the Sacramento-San Joaquin Delta. Approximately one-third of the marsh is tidally influenced and the remainder consists primarily of diked wetlands managed to attract waterfowl. Water inflow to the marsh is provided by a number of sources including tidal inflow through lower Suisun and Montezuma Slough, direct river inflow via the Sacramento and San Joaquin Rivers through upper Montezuma Slough and from a number of local tributaries within the marsh including Green Valley, Suisun, Ledgewood, and Denverton Creek. Flow into the system is highly seasonal and is derived from winter rain pulses and spring and early summer snowmelt from the various mountain regions surrounding the Sacramento-San Joaquin watershed. Water movement through the marsh during some times of the year is regulated by tidal gates located on the Montezuma Slough close to its upstream end on the Sacramento River.

Within Suisun Marsh, fish habitat availability and type changes depending upon the slough location, tide height and freshwater outflow. Sampled sloughs vary in size from 7-10 m wide and 1-2 m deep to 100-150 m wide and 2-6 m deep. Tidal influences on water depth can exceed 1 meter during extreme tidal movements, which can significantly dewater small sloughs. Vegetative cover, bank slope, and slough substrate in addition to biological parameters including temperature and salinity vary depending upon slough size, type and location. Environmental conditions within the marsh vary depending upon freshwater inflow and location of slough. Salinities within the marsh fluctuate by location, with the southwestern corner of the marsh having the highest salinities and southeastern sloughs having the lowest salinities. Salinity within the northern areas of the marsh is generally intermediate and is influenced by local stream inflow. Salinity within Suisun Marsh has ranged from 0 to near 17 ‰ during the course of the study, peaking in the autumn of drought years and falling during periods of high outflow in spring (Meng *et al.* 1994). The proximity of Suisun Marsh to the large upper bay system (Grizzly, Suisun, Honker Bay) and the considerable, but often unpredictable, amount of freshwater inflow from the Sacramento-San Joaquin and numerous local tributaries has influenced the catch of fish within the marsh. Over the course of the study 54 species (Table 1.2) have been captured within Suisun Marsh (29 native species and 25 alien species). Many of the occasional native species inhabitants of the marsh are dependent upon higher salinity conditions (12 species) and as expected their presence corresponds to periods of high salinity. The remainder of the native species are positively influenced by periods of low and intermediate salinity. The majority of alien species captured within the marsh are almost entirely dependent upon freshwater (excluding gobies and striped bass which account for the greatest alien fish abundance) and therefore have been most abundant in the marsh during periods of high freshwater inflow and low salinity (Matern et al. 1998). Additionally, a large number of species are only found in the marsh on a seasonal basis This is most notable for species that spawn in areas upstream or downstream of Suisun Marsh, and that have larvae or juveniles that rear in or pass through Suisun marsh on seaward or freshwater migrations.

Part 1: Suisun Marsh Fish Survey
January 2001 - December 2001

Introduction

The primary objectives of the Suisun Marsh fish study (juvenile and adult) are: (1) to record long-term changes in fish populations due to environmental fluctuations and species introductions and add to the growing database on environmental changes in the San Francisco Estuary; (2) to monitor the distribution and abundance of native species of the marsh, especially delta smelt, longfin smelt, chinook salmon, and splittail; (3) to track the movement of alien species, especially new invaders such as the shimofuri goby, shokihaze goby and Asian clam; and (4) to study the effects of the Montezuma salinity control gates and other proposed changes in water circulation on fish populations. Original sampling efforts within Suisun Marsh consisted of otter trawling and beach seining and were directed towards the juvenile and adult life history stages of fish. Catches of shrimp and clams have been incidental to the fish catch, but have been consistently recorded throughout the course of the study. Changes in species composition and abundance have occurred over the course of the study and are likely a result of changing environmental conditions and the continued invasion of the marsh by introduced species (Moyle et al. 1986, Menge et al. 1994, Matern et al. *in press* (see also UC Davis - Trends in Fish Populations of Suisun Marsh, 1994 – 2000). In general, abundance of the various species within the marsh has been declining since the early sampling years (1980 and 1982) with only brief periods of resurgence often associated with wet years. This section of the report (Part 1) presents the findings from the twenty-second year (2001) of the Suisun Marsh juvenile and adult fish survey.

Methods

Field methods:

Since 1979 monthly fish sampling has been conducted at numerous sites within Suisun Marsh. In the early sampling years (prior to 1994) a total of 12 sloughs and 27 sites were sampled (Table 1.1A, Figure 1.2). A majority of these historic sites were sampled only in the early years of the project (primarily 1980 and 1981) with 17 sites being sampled consistently up until 1994. Currently (after 1994), 21 sites within 9 sloughs are sampled for adult and juvenile fish (Table 1.1B, Figure 1.3). Latitude and longitude coordinates for currently sampled sites were obtained (± 100 m) using a Global Positioning System receiver (adjustments made by Alan Kilgore of the California Department of Fish and Game's Technical Services Branch GIS; Table 1.1B). Data from all historic sampling sites are included in this report because: (1) the entire data set reported here is available on the IEP website (http://www.iep.water.ca.gov); (2) The data are representative samples from within Suisun Marsh; and (3) the data provides a more robust comparison between fish catch in early sampling years and current catch.

Sampled sloughs vary in size and depth. Small sloughs sampled included Peytonia, Boynton, Spring Branch, Cutoff, Goodyear, Denverton, and Nurse (which is wider than the others but of comparable depth). Historically sampled sloughs including Hill, Wells, and Grant Slough, are also small in size. Large sloughs sampled include Suisun and Montezuma.

Trawling was conducted using a four-seam otter trawl with a 1 X 2.5 m opening, a length of 5.3 m, and mesh sizes of 35 mm stretch in the body and 6 mm stretch in the cod end. The trawl was towed at approximately 4 km/hr for 5 minutes in the small sloughs and for 10 minutes (to compensate for small catches) in the large sloughs. In Suisun and Denverton sloughs the monthly sampling was augmented with 10 m beach seines having a stretched mesh size of 6 mm. For each site the tidal stage, temperature (°C), salinity (‰), specific conductance (μS), water transparency (secchi depth in cm), and dissolved oxygen were recorded.

Contents of each trawl or seine were placed into large containers of water. Fishes were identified, measured to the nearest mm standard length, and returned to the site of capture. When possible, sensitive native species were processed first and immediately released. The abundance of several common macroinvertebrates were also recorded including the overbite clam and the shrimps *Palaemon macrodactylus* and *Crangon franciscorum*. It is quite likely that the 2001 abundance of *Palaemon* includes the recent invader *Exopalaemon modestus*, whose presence within the marsh was recently confirmed. This is supported by the finding that a majority (> 95%) of the *Palaemon* collected in winter 2002 (January – February) were indeed *Exopalaemon modestus* and the fact that a significant increase in abundance of *Palaemon* was observed in the Fall of 2001 in other localities (M. Nobriga (DWR) personal communication). Because positive identifications were not made in 2001, this report will present data at the level of genus (*Palaemon*). Mysid shrimps were pooled into one category, "mysids," and given an abundance ranking: 1 = 1-3 shrimp, 2 = 3-50 shrimp, 3 = 51-200 shrimp, 4 = 201-500 shrimp, 5 = >500 shrimp. The index was necessary because most mysids pass through the trawl and those that remain in the net are difficult to accurately count. Chinese mitten crabs (*Eriocheir sinensis*) were sexed and measured to the nearest mm maximum carapace width.

A complete historical list of common and scientific names for all of the fish species captured is presented in Table 1.2 and values used in constructing all charts are listed in the appendix.

Results and Discussion

<u>Environmental parameters:</u>

Outflow

From 1979 until fall of 1983 outflows varied annually and seasonally and salinities, temperatures, and water transparencies reflected the shifting influences of saltwater intrusion and freshwater runoff. During the drought years of 1985-1992 salinities stayed above 2 ‰ for all months except three (February 1986, March 1986 and March 1989). The above normal water year of 1993 resulted in salinities below 2.0 ‰ from February through June (Table 1.3) and a yearly average of 2.4 ‰ (Table 1.4). 1994 was a critical year and the yearly average rose to 4.3 ‰ (Table 1.4). Although the years 1995 through 2000 were all classified as being above normal or wet years (DWR DAYFLOW data), they were different in the timing and magnitude of rainfall and environmental conditions. This also likely had different ecological effects. The 2001 water year was classified as dry (DWR DAYFLOW data) with less than one-half the maximum outflow observed during 1999 / 2000 water year (Figure 1.4).

Salinity

Salinities in Suisun Marsh between 1999 and 2001 returned to a typical pattern following the exceptional year of 1998, throughout which salinity remained below 2 ‰ (Table 1.3). In 1999 salinities remained below 2 ‰ from January through July, but increased to a high of 5.4 ‰ in November. Salinity in 2000 remained below 2 ‰ from January through June but increased to a high of 6.8 ‰ in October. Salinity in 2001 remained below 4 ‰ from January through June, but then increased to a maximum of 9.2 ‰ in October. The average salinity in December 2001 dropped to 1.8 ‰, likely due to increased precipitation and outflow. Yearly average salinities between 1999 and 2001 were 2.4, 3.1, and 4.1, respectively (Table 1.4).

Between 1996 and 2000 the delta outflow was characterized as being relatively high, although the heavy rainfall had varying effects on the salinity of Suisun Marsh. In 1995 and 1998 the rains fell over a prolonged period, lasted relatively late into the year, and had lasting effects on the salinity of the marsh. In 1996, 1997, 1999, and 2000 the rains were early, concentrated, and had only short-term effects on the salinity. In recent dry and critical years salinities have often been lower than in previous years with similar amounts of rainfall. This is especially notable from October to March and could be a result of the current management decisions in Suisun Marsh, including the operation of the Montezuma salinity control gates. For example, 1994 was a critical year but mean salinity was lower (Table 1.4) than for several other dry and critical years (1987, 1990, 1991, and 1992) and equal to the salinity of another critical year, which occurred just prior to the full operation of the salinity control gates (1988). In 1989 no fall sampling was conducted, resulting in an artificially low mean salinity for that year.

Temperature and Water Transparency

Temperature regimes have shown no easily detectable changes (Table 1.3, Table 1.4). Water transparency (secchi depth) has historically decreased in response to high outflows and increased during periods of low outflow (Table 1.3, Table 1.4). For example, mean secchi depths were greater in 1996 than in 1995 for every month but February, the only month in which 1996 outflow exceeded that of 1995. Inexplicably, secchi depths in 1998 were higher during the high outflow months of March and April than they were during most low outflow months (Table 1.3). Secchi depths increased in 2001 with the yearly average being the third highest since 1980. Spring and summer secchi depth readings were most noticeably elevated above previous years.

Dissolved Oxygen

Dissolved oxygen monitoring was initiated in the fall of 1999, following a local pond discharge, which discolored water and resulted in a fish kill. In this report we have included the average monthly and yearly dissolved oxygen concentrations for the 2000 and 2001 sampling seasons (see Table 1.3 and Table 1.4). As a cautionary note, as with all environmental parameters, using averages masks potentially relevant biological parameters such as minima and maxima, which are more likely to affect aquatic organisms. Presentation of such data is beyond the scope of this report, thus a more detailed report is planned, which will address the high variability of dissolved oxygen levels observed throughout the marsh on both a spatial and temporal scale. Average dissolved oxygen levels in 2000 and 2001 rarely dropped below 7 mg/l O_2, except in the fall of 2001. In the fall of 2001 average dissolved oxygen values of 5.6 and 6.2 mg/l O_2 were observed in October and November, respectively.

General trends in fish abundance:

Throughout the twenty-two years of fish sampling in Suisun Marsh, otter trawl catches of native and alien species have shown considerable population fluctuations (Figure 1.5). The largest fluctuations have occurred in the abundance of alien species with abundance fluctuations as high as 150 % over a 2-3 year period. These extreme fluctuations are largely a result of successful recruitment of age 0 fish. Understanding factors responsible for successful recruitment of introduced species will provide some insight into these large and periodic (1- 3 years) cycles. Before taking into consideration the 2000 and 2001 fish catch, the general trend in abundance of introduced species over the twenty-two years of sampling in Suisun Marsh has been an overall decline. However, the abundance of alien species in 2000 (average of 27.8 fish / trawl) was the highest since sampling began in 1979. In 2001, the number of alien species remained high, but dropped to the fourth highest catch overall with 23.4 fish caught per trawl.

The wildly fluctuating catch of alien species has been strongly influenced by the changes in abundance of relatively few species, primarily striped bass, yellowfin goby and shimofuri goby. These three species have accounted for, on average, 90% of the annual catch of alien species through 1997 (Figure 1.6 and 1.7, respectively). The abundance of shimofuri goby has declined considerably since 1997 with the alien species catch now being dominated by yellowfin goby and striped bass. In 2001, striped bass dominated the catch (> 50% of total catch) with yellowfin goby declining considerably from 2000 levels and making up only 6.4% of the total catch.

Native species abundance has not fluctuated as wildly as alien species abundance. However, a general decline in native species abundance has occurred since 1980. The greatest decline in native fish catch occurred between 1980 and 1985 when populations crashed from highs in both 1980 and 1981 to dramatic lows in 1984 and 1985 (Figure 1.5). Over the period of 1994-2001 there has been a gradual increase in native fish abundance (Figure 1.5). Despite this apparent increase in native fish abundance, only the Sacramento splittail has shown consistent increases during this time period with their second highest catch since 1980 occurring in 2001 (Figures 1.8 – 1.11 respectively). Catch of the remaining native species have either fluctuated considerably (Figure 1.9 – 1.11) or have remained at relatively low levels (Figure 1.11).

During the course of the Suisun Marsh fish study, native fish abundance has rarely exceeded alien fish abundance. Exceptions include the period between 1980-1982 and 1987-1988 and a single year in 1998 (attributed to a huge stickleback catch in a single trawl; Matern et al. 1998). Since 1982, native fish catch has exceeded alien fish catch only during times of exceptionally low alien fish catch rather than during periods of exceptionally high native fish catch. This trend suggests that current conditions, either physical or biotic, are not suitable for native species to return to earlier recorded abundances.

Fish catch between 1995 and 2001 has varied depending upon slough sampled (Figure 1.12). In general, there appears to be three average levels of abundance among sampled sloughs (low, 20 fish / trawl; intermediate, > 20 and < 35 fish / trawl; and high - > 35 fish / trawl). Because of the large distance separating upper and lower sampling sites in Suisun Slough (Figure 1.3) and the large differences in catch, the slough is broken up into two locations for discussion purposes (Upper and Lower Suisun Slough). Lowest catches on average have been within Montezuma, Boynton Cutoff, Upper-Suisun and Nurse sloughs (Figure 1.12). All sloughs with a low catch, with the exception of Boynton and Cutoff sloughs are relatively large in size, thus low catches may be attributed to poor catch rates associated with size of slough or due to fewer individuals actually occupying those larger sloughs. Boynton and Cutoff sloughs are actually relatively small in size, thus size alone may not be responsible for the observed low catch rates. Rather, other factors either natural or anthropogenic could be influencing catch rates there. It is interesting to note that Boynton Slough receives sewage outflow from the Fairfield Sewage Treatment Plant, which may be creating physical conditions unfavorable to fish. Intermediate levels of catch between 1995 and 2001 occurred in Peytonia, Denverton and Goodyear sloughs and the highest catch occurred in Lower-Suisun and Spring Branch sloughs. The sloughs with the three highest catch rates (Good Year, Spring Branch, and Suisun Lower; Figure 1.12) were heavily influenced by the abundance of striped bass, which comprised 50.0, 51.3, and 72.7 % of the total catch, respectively.

Delta smelt and longfin smelt:

Catch of delta smelt (DS) increased in 2001 to a total of 33 individuals with the catch per trawl being the third highest catch since 1980, although total numbers remain relatively low overall (Figure 1.9). Longfin smelt (LFS) catch further declined in 2001 to a total of 288 individuals, but the average catch per trawl was still the ninth highest since 1980 (CPUE of 1.16; Figure 1.9).

A strong seasonal pattern in LFS size at capture was evident between 1999 and 2001 and has also been observed in previously sampled years (Matern et al. 1998). In 1999 and 2000, a majority of LFS captured from May through October were < 50 mm in length (< 35mm in May up to 50 mm in October). The size of individuals captured in November and December were between 50 and 100 mm. Large adults captured in January and February in all three years were presumably adults from the previous years cohorts. These fish likely spawned within Suisun Marsh, as is evident by the presence of larval longfin smelt present in our samples as early as the first week of our larval fish sampling (February 4, 2000 and February 6, 1999). According to Dryfoos (1965) LFS eggs hatch after approximately 40 days at 7 °C, which suggests that the LFS larvae captured in February were likely to have been spawned in December or January. The presence of high numbers of LFS larvae between February and April 2000 and the presence of large LFS up until February 2000 suggests that LFS experienced an extended spawning season in 2000. Typically our catch of large LFS drops to zero after February and relatively few adults are observed until November of that same year. The lack of LFS following the spawning period (December – March) may be a result of post spawning mortality (Moyle 2002) or adult movement to other areas of the estuary.

Striped bass:

Striped bass catch in 2001 was the third highest catch rate (17.0 striped bass / trawl) since sampling in Suisun Marsh began. A total of 4246 striped bass were captured by otter trawl making up over half of the total catch (8070 individuals of all species) in 2001. These numbers are up from the striped bass catch in 1999 and 2000, which comprised 31.5 and 30.7 %, respectively, of the total fish catch in otter trawls. The abundance of striped bass has fluctuated considerably since 1979 with very low abundances observed in 1990, 1994, and 1998 followed by dramatic increases in 1991-1992, 1997, and 1999 - 2001. YOY striped bass make up a majority of the total striped bass catch, thus fluctuations resulting from successful recruitment in a given year are largely responsible for the dramatic changes in striped bass abundance. For example, the 2001 catch of striped bass < 100 mm comprised approximately 94% of the total with a majority of those individuals being less than 60 mm.

Within the marsh, it appears that based on catch rates three areas are heavily used by striped bass. These areas include lower Suisun, Spring Branch and Goodyear sloughs, in which nearly 64% of all the striped bass in Suisun Marsh were caught in 2001. Taking a closer look at catch rates in lower Suisun Slough, the location of highest average catch in Suisun Marsh between 1995-2001 (see Figure 1.12), we see that striped bass comprised over 73% (1052 of 1447 individuals) of the fish captured in otter trawls. It is uncertain why these areas are so heavily used by striped bass, but it is likely that a high availability of prey, shallow depth, and proximity to the larger bays (at least in the case of lower Suisun and Goodyear) make these areas important for striped bass rearing. One implication of these high abundances of striped bass in Suisun Marsh is that they could potentially be affecting prey availability for other fish species, at least during times of their greatest abundance (summer months).

Splittail:

Catch of Sacramento splittail in otter trawls in 2001 (1186 individuals) was the second highest since sampling began in 1979. The 2001 catch rate is a dramatic increase from the low catch rates observed in the late 1980s and early 1990s and is part of a continued increase observed since 1994. The 2001 splittail catch was comprised of multiple age classes and was unlike the 2000 catch, where a majority of individuals were YOY; nearly 65 % (734 of 1186 individuals) of the 2001 fish were greater than 100 mm SL.

Splittail are generally most abundant within three sampled sloughs: Spring Branch, Peytonia and Goodyear. In 2001, catch within these three sloughs comprised over (76 %) of the total splittail catch despite the fact that the sites within those sloughs comprised only 40 % of the total sites sampled in Suisun Marsh. It is not known why abundances are so high within certain sloughs, but a planned investigation examining the environmental and biotic conditions present within those sloughs should provide some insight. One likely explanation centers on the fact that all three of the sloughs are small and shallow, which may result in increased primary productivity and food availability as well as reduced predation risk from large striped bass and Sacramento pikeminnow.

The splittail catch in beach seines in 2001 (120 individuals) declined from the 2000 catch (207 individuals), but is still the fifth highest catch since sampling was initiated in 1979. Splittail YOY made up a large percentage of the beach seine catch and were found at both seining sites by the middle of May.

Chinook salmon:

The total catch of chinook salmon in 2001 in both otter trawls and beach seines was 10 individuals (2 otter trawls and 8 beach seines). This is the same total catch as in 2000, but is down from a total catch of 16 individuals in 1999 and an all time high in 1995 (first year Denverton Slough was beach seined) in which 50 individuals were captured. All chinook salmon from 1995 through 2001 were fall run as determined using Frank Fisher's (1992) length-at-date criteria and were made up predominantly by YOY.

The origin of the YOY chinook salmon captured in Suisun Marsh is largely unknown. However, the small size of these salmon, their relatively high density in Denverton Slough, and landowner accounts of spawning adults have forced us to consider the possibility that these salmon were spawned in the area and did not recruit from the Sacramento or American Rivers as was previously assumed. Regardless of the origin of chinook salmon captured in Suisun Marsh, it appears as if rearing of salmon within the marsh occurs during some years, as evidenced by the presence and growth of salmon in the marsh for a period up to several months (e.g. 1995). The opportunity for salmon rearing within the marsh is likely limited by high water temperatures, which can affect survival and growth. In 1995, average recorded temperatures in Suisun Marsh in March and April were 13 and 15.1 °C, respectively. Average temperature in May 1995 increased abruptly to 21 °C. The monthly average temperatures in March and April in 1996, 1997, and 1998 were considerably higher than those recorded in 1995 (Table 1.3). The second highest catch of juvenile chinook salmon in the marsh occurred in 1999 a year in which the average monthly temperatures were very similar to those observed in 1995.

Goby:

Three alien species of goby were collected in Suisun Marsh in 2001. They include the yellowfin goby, shimofuri goby and shokihaze goby (Figure 1.7). The shokihaze goby (*Tridentiger barbatus*) was first collected in Suisun Marsh in 1999 when a single individual was captured. In 2000, shokihaze goby were absent from our trawls, but had begun to increase in abundance elsewhere in the estuary (Tom Greiner CDFG personal communication). A total of 34 bearded goby were captured during our 2001 sampling with a majority of these being juveniles.

Little is known about the shokihaze goby, but in the the San Francisco Estuary, it has been found in both fresh and brackish water environments with salinities as high as 28 ppt (Tom Greiner, CDFG, personal communication). According to Dotu (1956), shokihaze goby in Ariake Sound, Japan, can live longer than 3 years and reach a size greater than 120 mm, but may mature as early as the first year at a size of 40 – 85 mm. The largest shokihaze goby captured in the San Francisco Estuary was greater than 120 mm total length (Steve Slater, CDFG, personal communication). In Japan, shokihaze goby inhabit oyster beds on muddy tide flats (Dotu 1956). Within the San Francisco Estuary, shokihaze goby are typically found in deep channel habitats, as is the case in Suisun Marsh. The diet of shokihaze goby in the San Francisco Estuary is unknown, but those captured in Ariake Sound consumed annelids, small crustaceans squid, and young fish including other gobies (Dotu 1956). The shokihaze goby thus has the potential to have negative effects on small benthic fishes and invertebrates in newly invaded habitats such as Suisun Marsh.

Yellowfin goby catch declined considerably in 2001 (513 individuals; 2 fish / trawl) from the high observed in 2000 (3427 individuals; 13.6 fish / trawl). The catch of yellowfin goby by beach seine in 2001 (708 individuals) also dropped considerably from the 2000 catch (2288 individuals). Historically, the yellowfin goby has shown periodic peaks in abundance throughout the span of the Suisun Marsh fish sampling program, most notably in 1993, when high recruitment resulted in a mean catch of 16 gobies per trawl. Catches in 1994 plummeted to less than one goby per trawl but rebounded to almost nine gobies per trawl (most of them YOY, including 665 individuals smaller than 40 mm SL) in 1995. In 1996 mean catch again fell to less than one goby per trawl and remained low until 1999 when goby increased in abundance to over 6 gobies per trawl (Figure 1.7). Historical peaks in abundance of YFG in Suisun Marsh have been short-lived, typically lasting only a year. Thus, the decrease observed in 2001 is fairly typical and will most likely also be short-lived. It is uncertain whether the wildly fluctuating abundances of yellowfin goby is typical for this species or if biotic and or environmental conditions are influencing its abundance.

The shimofuri goby was first collected in Suisun Marsh in 1985 and has subsequently spread throughout the Sacramento-San Joaquin Delta and into southern California via the State Water Project System (Matern and Fleming 1995). Its population peaked briefly in 1989 when it was the most abundant species collected in our trawls but has declined considerably since then. The shimofuri goby catch in our otter trawls in 2001 (659 individuals) was the fifth highest since it first appeared in 1985. Beach seine catch of shimofuri goby increased in 2001 to 122 individuals up from 64 individuals in 2000. The beach seine catch in 2001 was the second highest since 1985.

The shimofuri goby spawns from March through August in Suisun Marsh and we believe that most fish live only one year (if they were born early) or two years (if they were born late). This somewhat annual life cycle is likely to account, at least partially, for the observed wide fluctuations in shimofuri goby abundance. It is also interesting to note that following the initial period of invasion; shimofuri goby have reached their greatest densities only during periods of low yellowfin goby abundance (Figure 1.7). The observed abundance patterns may be a result of differential responses to environmental conditions, but could potentially be a result of biotic interactions between the two species.

Prickly sculpin, Pacific staghorn sculpin, and Sacramento sucker:

The catch of native prickly sculpin, has been highly variable throughout the course of this study (Figure 1.11). In 2001, prickly sculpin catch declined significantly with only 18 individuals captured in otter trawls and 1 individual captured by beach seine. The low numbers of fish observed in 2001 is a six fold decline from the 2000 catch and is the second lowest catch in the history of the project.

Moderate outflows in 2001 may have contributed to the low recruitment of prickly sculpin, but other environmental and biological factors may also have played a role.

Marsh populations of staghorn sculpin, a euryhaline marine species, generally decrease in years with high runoff. From 1992 to 1994, catches were near the all time low recorded in 1983. In 1995, catches increased 10-fold despite the heavy freshwater outflows (Figure 1.11). This inconsistency may be explained by the fact that Pacific staghorn sculpin spawn in the winter and therefore experience different spawning conditions from most of the other resident fishes in the marsh. From 1996 through 2001, the pattern (low abundance with moderate to high outflow) re-emerged, with catches falling in the wake of heavy outflow. A total of 46 staghorn sculpin were collected by otter trawl and 213 individuals by beach seine in 2001 (Figure 1.11).

Sacramento sucker, like many native fishes, have been in a long-term decline in Suisun Marsh. Despite a gradual increase in abundance between 1996 and 1998, catches have remained less than one-fifth the catches of 1980 and 1981 (Figure 1.11). Catch of Sacramento sucker in 2001 (44 individuals) was similar to the 1999 and 2000 catch, which were slightly below the previous three years catch. This species may be capable of rebounding if given the right conditions because it is relatively long-lived and can tolerate several years between successful spawning. Presumably all Sacramento suckers in the marsh recruit from inflowing streams.

Tule perch:

Tule perch have historically been one of the most abundant native fishes in the marsh (Table 1.5). This species is the only freshwater representative of the surfperch family Embiotocidae. Tule perch are year-round residents of the marsh and, like all surfperches, are livebearers. Tule perch catch in our trawls peaked from 1981 to 1982 and again from 1987 to 1988 but for the most part have remained very low for the last decade. In 1999 and 2000 the catch of tule perch in Suisun Marsh declined significantly to the lowest levels ever recorded (Figure 1.10, Table 1.5). However in 2001, tule perch abundance increased significantly (444 individuals) and catch rates were the eighth highest since 1980 and the largest catch since 1988. The rebound of tule perch may only be short-lived, but the presence of multiple age-classes (approximately 3) is encouraging and suggests that this species may continue to become more abundant if conditions remain favorable. The reasons for this resurgence are unknown.

Uncommon species:

Representative members of the family Centrarchidae are typically rare in Suisun Marsh (Table 1.5). The black crappie is the most abundant with high catches typically occurring in years with moderate to high precipitation and outflow. In 2001, 79 black crappie and a single bluegill were captured. Three species in the family Ictaluridae are typically caught in Suisun Marsh, but like centrarchids, their catch is limited and is generally restricted to sloughs where salinities remain low. In 2001, 15 black bullhead, 109 white catfish, and 2 channel catfish were captured. White catfish and channel catfish are typically most abundant in Denverton and Nurse Slough, but also occur in low numbers (mostly white catfish) in other sloughs of the marsh. Black bullhead are generally found within Peytonia, Boynton and Spring Branch sloughs. In 2001, a single hardhead was also captured making it the first time we have captured this native cyprinid in Suisun Marsh.

Species collected in beach seines:

Fish catch by seine has fluctuated considerably between 1995 and 2001 with between 2000 and 9000 individuals captured. The mean number of fish per seine haul over this time period was 68 individuals. In 2001, 6279 individuals were captured by seine or 74.8 fish / seine. This is the fourth highest catch since 1995, when Denverton Seining Beach was added to the regular sampling. Based on fish catch over this time period, we see that some fish species are more susceptible to capture by seining as compared to trawling. For instance, from 1995 to 2001 most Sacramento blackfish, bigscale logperch, chinook salmon, Sacramento pikeminnow, and western mosquitofish were taken by seining. The most striking result was that we captured a majority of inland silverside by seine and relatively few by trawl (Table 1.5, Table 1.6). The inland silverside was the most abundant species captured by seine in 2001 (4284 indiv.) and comprised 68 % of the total catch. Yellowfin goby were the next most abundant species (708 indiv.) comprising 11.3 % of the catch. Inland silverside and yellowfin goby typically dominate our seine catch and in 2000 they collectively comprised over 79 % of the total catch.

Invertebrates:

The catch of mysid shrimp (as estimated by an average rank abundance) in Suisun Marsh, primarily *N. mercedis*, was high in the early sampling years especially between 1980 and 1990 (Table 1.4). More recently mysid shrimp abundance has declined considerably, but this data has been confounded by the continued invasion of several alien species of mysid shrimp. The impacts of these newly introduced mysids on the native fauna is largely unknown but since their invasion in 1992 it appears that several species of mysids, primarily *Acanthomysis bowmani*, have been replacing the native species *N. mercedis* in the San Francisco Estuary (Orsi and Mecum 1994). It is not possible to identify mysid shrimp under field conditions; thus our current (since 1992) measure of mysid shrimp abundance likely reflects a combination of native (*N. mercedis* and to a lesser extent *N. kadiakensis*) and alien species (*A. bowmani* + others).

Our mysid catch in 2001 declined from a nine year high in 2000 (average rank of 1.5) to a relatively low level in 2001 (1.2). These average ranks are still considerably below the highs observed between 1980 and 1990. Investigations into the composition and abundance of mysid shrimp in Suisun Marsh are ongoing with Orsi (1998) reporting that in the fall of 1997 no *N. mercedis* were found in the large sloughs of Suisun Marsh (Suisun and Montezuma) and that *A. bowmani* was abundant. In October 1998, Orsi (1999) found densities of *A. bowmani* up to 179 m^{-3} in Suisun Slough and found *N. mercedis* to be present in low numbers. Preliminary results from our mysid catch in the larval fish trawls shows both species to be present and in 1999 over 60% of all mysids collected between February and May were found to *N. mercedis* and another native species *N. kadiakensis*. Possible differences in results may be attributed to sampling location within the marsh. Our sites are primarily within the smaller upstream sloughs whereas larger sloughs adjacent to Grizzly Bay are sampled by Orsi.

The abundance of *C. franciscorum* in Suisun Marsh has fluctuated yearly within the range of 12 to 68 individuals per trawl until 1997, when our average catch increased to 128 individuals per trawl (Figure 1.13). Between 1998 and 2001 the abundance of *C. franciscorum* has remained at or below 35 individuals / trawl. The large fluctuations in abundance of *Crangon* may be explained by fluctuating environmental conditions and the positioning of the population within the estuary. For example, in 1998 the highest density of *C. franciscorum* was found downstream of the marsh (Hieb 1999). Alien species within the genus *Crangon* have recently been introduced into the estuary, but it appears that, at least for now, the species found within Suisun Marsh is still the native *C. franciscorum*.

P. macrodactylus prefers fresher water than *C. franciscorum* and hit an all-time low in 1994 and, despite high outflows and low salinities, it hit lows again in 1995 and 1996 before rebounding slightly in 1997 and 1998 (Figure 1.13, Table 1.4). In 1999 and 2000, *P. macrodactylus* again declined in abundance to very low levels (Figure 1.13). Because *P. macrodactylus* feeds on mysid shrimps, their decline may be related to low abundance of mysids in recent years (Jim Orsi, DFG, pers. commun.) or could be attributed to mysids being more abundant in other areas of the bay-delta. However, during the 2001 season, *Palaemon* abundance increased 16 times from their catch in 2000 making it the highest abundance since sampling began in 1979, while mysid shrimp abundance remained low. It is quite likely that the current high abundance of *Palaemon* observed in the marsh is due to the recent invasion by *Exopalaemon modestus*. This new invader has recently been found in freshwater portions of the upper San Francisco Estuary and delta and between December and February 2002 over 90% of the *Palaemon* captured in Suisun Marsh were in fact *Exopalaemon modestus*.

Another introduced species occurring in the marsh is the overbite clam, *Potamocorbula amurensis*. This bivalve can attain densities of over $40{,}000/m^2$ (Heather Peterson, DWR, pers. commun.) and is an efficient filter-feeder that is disrupting the food web in the San Francisco estuary. Based on conservative estimates, these clams filter all the water in the North Bay 1-2 times per day. A consequence of their incredible filtering capacity is thought to be the virtual elimination of the spring phytoplankton bloom (Kimmerer 1998) and the summer/fall chlorophyll bloom as well as a shift from a pelagic food web to a benthic one (Thompson 1998).

The historical occurrence of the overbite clam in Suisun Marsh has been primarily in lower Suisun Slough (SU3 and SU4) and lower Goodyear Slough. In 2001, 7226 individuals were collected at 6 sites in Suisun Marsh including lower Suisun (SU3 and SU4), middle and lower Goodyear (GY2 and GY3) and single individuals collected in both Montezuma (MZ1) and Nurse Slough (NS3). Most of these individuals (7100) were collected in two trawls in lower Suisun in June and July. Typically, individuals captured in Suisun Marsh are small (< 5 mm) and are mainly collected between January and September 2001. It is interesting to note that the occurrence of the overbite clam in our trawls is typically associated with the presence of aquatic vegetation in our nets. This may suggest that there is limited substrate for attachment by the overbite clam within the sloughs of Suisun Marsh.

In 1996, four Chinese mitten crabs (*Eriocheir sinensis*) were collected in Suisun Marsh, marking the first time they had been collected upstream of the Carquinez Strait. In 1997, we collected

19 Chinese mitten crabs. The mitten crabs captured in 1997 were primarily males less than 52 mm MCW and were collected between August and December. In 1998 and 1999, we collected 149 and 171 mitten crabs, respectively, mainly in Suisun Slough. The catch in both 1998 and 1999 was comprised of both sexes and a wide range of sizes. Since our first collection of mitten crabs, they have been captured in several locations upstream in the Sacramento-San Joaquin delta (Veldhuizen 1997). In the Fall of 1998, 20,000 to 25,000 mitten crabs per day were collected for several weeks at the federal fish facilities in Tracy (Brown 1998). More recently it appears as if mitten crab abundance within Suisun Marsh is declining with only 17 individuals captured in 2000. However in 2001, mitten crab abundance again increased and 98 individuals were captured.

Conclusions

Fish catch in Suisun Marsh has fluctuated considerably since sampling began in 1979. Throughout this time period both native and introduced species have declined in abundance from their historic levels with only slight sustained increases in abundance. Among the introduced species, striped bass and yellowfin goby are generally the most abundant and together often exceed the abundance of all native species combined. Both native and introduced species abundance appears to fluctuate based upon environmental conditions, largely influenced by water year and ultimately the amount and timing of freshwater outflow (Matern et al. in press). Historically abundant species including longfin smelt, splittail and tule perch have in recent years only been captured in relatively low numbers. However, in 2001 our catch of Sacramento splittail and tule perch increased dramatically. For the Sacramento splittail, this caps off a slight increase observed between 1995 and 2000. Tule perch abundance on the other hand has fluctuated over this same time period before peaking in 2001. It is encouraging that this current peak in tule perch abundance is not due primarily to a sudden increase in young-of-year. Rather multiple age classes now dominate the tule perch catch and another favorable year (environmentally) will most likely result in an even more dramatic increase in tule perch abundance. The increase in abundance of tule perch and splittail in 2001 is encouraging because historically those two species comprised the largest percentage of the native species catch. However other native species, also abundant in early sampling years (Sacramento sucker, prickly sculpin, delta smelt and longfin smelt), have failed to rebound.

Factors responsible for native species declines are largely unknown, but are likely attributed to habitat alteration and environmental conditions, as well as impacts brought upon by the introduction of numerous fish and invertebrate species into the Sacramento-San Joaquin estuary. The continued expansion of exotic species and the looming threat of future species introductions will likely further affect native species abundance. A lack of thorough understanding as to how alien species may affect the aquatic community in Suisun Marsh limits our ability to predict future trends in native and alien species abundance. Continued monitoring of the fish populations in Suisun Marsh will enable further evaluation of factors believed to be contributing to native and alien species declines.

Table 1.1A Historic Suisun Marsh sampling locations (Priori to 1994). Many historic sites were only sampled between 1979 and 1981 with consistent sampling of 17 sites through 1994 in Suisun, Peytonia, Boynton, Cutoff, Spring Branch, Good Year, Montezuma, Nurse and Denverton Slough.

Slough	Number of Sites
Suisun (SU)	3
Hill (HL)	1
Peytonia (PT)	1
Boynton (BY)	3
Cutoff (CO)	2
Grant (GR)	4
Spring Branch (SB)	2
Wells (WL)	3
Good Year (GY)	1
Montezuma (MZ)	5
Nurse (NS)	1
Denverton (DV)	1
TOTAL	**27**

Table 1.1B Current Sampling Sites (1994-present).

Slough	Site	Latitude	Longitude
Suisun	SU1	38° 13’ 2.0” N	122° 01’ 43.1” W
Suisun	SU2	38° 12’ 8.2” N	122° 02’ 22.7” W
Suisun	SU3	38° 08’ 22.0” N	122° 04’ 22.7” W
Suisun	SU4	38° 07’ 36.0” N	122° 04’ 51.4” W
Peytonia	PT1	38° 13’ 38.1” N	122° 03’ 4.5” W
Peytonia	PT2	38° 13’ 18.0” N	122° 02’ 34.5” W
Boynton	BY1	38° 12’ 40.0” N	122° 03’ 12.5” W
Boynton	BY3	38° 12’ 41.3” N	122° 02’ 38.3” W
Cutoff	CO1	38° 11’ 33.6” N	122° 01’ 35.5” W
Cutoff	CO2	38° 11’ 21.7” N	122° 01’ 13.1” W
Spring Branch	SB1	38° 12’ 2.8” N	122° 01’ 48.5” W
Spring Branch	SB2	38° 11’ 57.1” N	122° 01’ 53.5” W
Goodyear	GY1	38° 06’ 8.3” N	122° 05’ 36.2” W
Goodyear	GY2	38° 06’ 27.5” N	122° 05’ 52.1” W
Goodyear	GY3	38° 07’ 55.8” N	122° 05’ 10.4” W
Montezuma	MZ1	38° 05’ 36.6” N	121° 53’ 9.5” W
Montezuma	MZ2	38° 07’ 5.2” N	121° 53’ 18.5” W
Nurse	NS2	38° 11’ 0.3” N	121° 55’ 32.6” W
Nurse	NS3	38° 10’ 19.6” N	121° 55’ 41.8” W
Denverton	DV2	38° 12’ 10.6” N	121° 54’ 23.2” W
Denverton	DV3	38° 11’ 55.0” N	121° 54’ 53.9” W

Table 1.2 Fishes of Suisun Marsh.

Common Name	Scientific Name	Abbreviation
American shad	*Alosa sapidissima*	ASH
bay pipefish	*Syngnathus leptorhynchus*	BYP
bigscale logperch	*Percina macrolepida*	BLP
black bullhead	*Ictalurus melas*	BLB
black crappie	*Pomoxis nigromaculatus*	BC
bluegill	*Lepomis macrochirus*	BG
brown bullhead	*Ictalurus nebulosus*	BB
California halibut	*Paralichthys californicus*	CHA
channel catfish	*Ictalurus punctatus*	CC
chinook salmon	*Oncorhynchus tshawytscha*	KS
common carp	*Cyprinus carpio*	CP
delta smelt	*Hypomesus transpacificus*	DS
fathead minnow	*Pimephales promelas*	FHM
golden shiner	*Notemigonus crysoleucas*	GSH
goldfish	*Carassius auratus*	GF
green sturgeon	*Acipenser medirostris*	GS
green sunfish	*Lepomis cyanellus*	GSF
hardhead	*Mylopharodon conocephalus*	HH
hitch	*Lavinia exilicauda*	HCH
inland silversides	*Menidia beryllina*	ISS
largemouth bass	*Micropterus salmoides*	LMB
longfin smelt	*Spirinchus thaleichthys*	LFS
longjaw mudsucker	*Gillichthys mirabilis*	LJM
northern anchovy	*Engraulis mordax*	NAC
Pacific herring	*Clupea harengeus*	PH
Pacific lamprey	*Lampetra tridentata*	PL
Pacific sanddab	*Citharichthys sordidus*	PSD
Pacific staghorn sculpin	*Leptocottus armatus*	STAG
plainfin midshipman	*Porichthys notatus*	MID
prickly sculpin	*Cottus asper*	SCP
rainbow trout	*Oncorhynchus mykiss*	RT
rainwater killifish	*Lucania parva*	RWK
redear sunfish	*Lepomis microlophus*	RS
Sacramento blackfish	*Orthodon microlepidotus*	BF
Sacramento pikeminnow	*Ptychocheilus grandis*	SPM
Sacramento sucker	*Catostomus occidentalis*	SKR
shokihaze goby	*Tridentiger barbatus*	SKG
shimofuri goby	*Tridentiger bifasciatus*	SG
shiner perch	*Cymatogaster aggregata*	SP

Table 1.2 continued

Common Name	Scientific Name	Abbreviation
speckled sanddab	*Citharichthys stigmaeus*	DAB
splittail	*Pogonichthys macrolepidotus*	ST
starry flounder	*Platichthys stellatus*	SF
striped bass	*Morone saxatilis*	SB
surf smelt	*Hypomesus pretiosus*	SS
threadfin shad	*Dorosoma petenense*	TFS
threespine stickleback	*Gasterosteus aculeatus*	STBK
topsmelt	*Atherinops affinis*	TPS
tule perch	*Hysterocarpus traski*	TP
wakasagi	*Hypomesus nipponensis*	WAK
warmouth	*Lepomis gulosus*	WM
western mosquitofish	*Gambusia affinis*	MQF
white catfish	*Ameiurus catus*	WCF
white crappie	*Pomoxis annularis*	WC
white croaker	*Genyonemus lineatus*	WCK
white sturgeon	*Acipenser transmontanus*	WS
yellowfin goby	*Acanthogobius flavimanus*	YFG

Table 1. 3 Mean salinity (‰), temperature (°C), secchi depth (cm) and dissolved oxygen (mg/lO_2) per month. Seventeen sites were sampled in most months prior to 1994, while 21 sites were sampled after 1994.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Salinity (‰):										
Jan	1.4	4.4	1.9	0.4	0.2	---	2.7	3.9	3.3	---
Feb	1.4	2.8	1.5	0.3	0.7	2.5	0.6	2.5	4.7	2.9
Mar	1.8	3.0	1.5	0.1	0.6	2.2	0.7	2.5	6.1	1.3
Apr	1.6	2.1	0.4	0.3	0.8	2.9	1.1	3.1	3.3	3.4
May	1.3	3.0	0.8	0.6	1.9	3.3	2.8	4.3	3.5	3.5
Jun	1.6	3.9	0.6	0.4	2.7	---	4.4	7.7	4.6	5.3
Jul	1.3	5.3	0.7	0.2	---	4.9	4.3	7.2	4.6	6.6
Aug	3.0	6.8	1.5	0.4	3.9	8.0	---	6.1	5.4	6.5
Sep	4.2	7.9	1.8	0.4	3.6	8.3	4.0	6.4	4.7	6.3
Oct	---	7.6	0.9	0.3	3.4	10.2	3.3	9.6	4.5	---
Nov	4.4	8.8	1.3	0.2	2.7	8.5	4.1	9.5	4.2	5.0
Dec	4.6	2.8	0.7	---	---	7.5	4.7	7.0	2.7	6.3

Table 1. 3 continued

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Temperature (° C):										
Jan	10	9	8	8	8	---	10	7	10	---
Feb	11	13	9	13	12	8	15	12	10	8.6
Mar	12	15	13	13	16	11	17	15	15	15.4
Apr	17	18	14	15	16	18	19	20	19	17.2
May	18	20	13	19	21	22	21	19	20	20.6
Jun	20	21	20	19	23	---	20	19	22	19.4
Jul	20	23	24	20	---	25	21	23	22	22.7
Aug	22	22	20	20	26	20	---	22	23	21.5
Sep	20	20	21	20	24	19	19	21	18	19.7
Oct	---	17	17	18	15	17	17	17	14	---
Nov	16	15	10	11	13	9	14	13	12	11.2
Dec	9	11	9	---	---	5	9	80	6	10.7
Secchi (cm):										
Jan	23	27	22	28	30	---	22	29	30	---
Feb	23	19	26	22	22	25	18	20	20	29.7
Mar	20	18	21	19	17	23	18	18	18	17.4
Apr	18	17	20	20	16	18	19	21	26	15.0
May	16	19	14	16	23	23	16	20	20	13.6
Jun	15	20	17	17	41	---	16	21	28	19.8
Jul	16	21	15	19	---	22	19	25	23	---
Aug	22	24	16	20	30	24	---	30	25	22.8
Sep	26	35	18	27	35	33	21	34	30	20.4
Oct	---	39	20	19	28	40	24	30	31	---
Nov	25	34	19	26	28	50	24	31	30	22.3
Dec	27	19	26	---	---	41	29	24	28	28.4

Table 1. 3 continued

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Salinity (‰):												
Jan	4.2	8.1	7.1	2.1	2.8	1.0	1.2	0.5	1.4	1.0	2.3	2.7
Feb	3.6	6.5	4.5	1.4	1.5	0.7	0.4	1.1	---	0.7	0.9	3.9
Mar	4.4	3.1	2.5	0.9	1.2	0.3	0.6	1.1	0.9	0.6	1.1	1.0
Apr	5.4	2.6	2.2	1.7	1.8	0.7	0.7	1.7	0.9	1.2	1.2	1.3
May	5.7	5.5	4.8	1.1	2.0	0.3	0.8	2.7	1.1	0.8	1	1.9
Jun	4.2	7.5	6.6	0.9	4.0	0.2	0.7	4.1	0.7	0.9	1.7	2.6
Jul	5.7	8.4	7.8	2.2	6.1	0.2	2.4	5.1	0.6	1.8	3.4	5.1
Aug	6.4	8.9	9.7	2.5	7.7	1.0	3.4	5.3	0.9	2.6	3.7	7.3
Sep	7.3	8.4	9.4	3.5	6.9	1.0	4.2	5.4	1.1	4.0	5.1	8.1
Oct	---	9.7	10.2	4.4	5.5	1.5	6.3	6.7	1.2	4.4	6.8	9.2
Nov	9.3	8.1	8.1	4.1	5.6	3.8	4.4	5.9	1.8	5.4	5.9	6.4
Dec	8.8	8.4	4.4	4.1	3.0	2.0	2.0	2.7	1.0	4.5	3.7	1.8
Temperature (° C):												
Jan	8.1	6.7	8.1	8.2	9.5	9.8	9.9	12.7	10.9	6.1	11.4	8.3
Feb	10.3	12.2	11.5	12.4	11.0	13.2	13.6	11.7	---	11.3	12.2	11.7
Mar	15.5	11.8	15.0	17.6	14.9	13.0	16.3	17.8	17.1	13.6	14.6	12.7
Apr	19.0	15.0	16.6	17.1	18.0	15.1	19.4	18.5	15.3	16.6	17.5	15.3
May	18.9	17.7	19.5	20.1	19.4	21.8	19.1	19.8	16.8	18.3	19.2	20.0
Jun	21.0	18.4	19.2	24.3	19.9	22.4	21.3	23.3	18.8	19.0	20.2	22.5
Jul	21.3	20.3	22.3	22.2	21.3	21.3	21.4	22.9	23.3	22.2	20.3	20.2
Aug	24.1	20.9	20.3	23.1	23.0	22.3	19.7	20.6	20.8	20.4	20.6	21.9
Sep	20.7	19.1	21.1	20.0	20.5	19.7	19.1	21.0	19.9	19.7	22.6	19.6
Oct	---	19.1	21.6	19.0	17.9	16.2	15.0	15.4	15.8	19.2	14.5	17.8
Nov	12.3	15.3	19.0	12.0	10.5	16.1	14.0	13.9	12.4	12.8	10.6	15.6
Dec	9.5	9.4	11.0	11.9	8.6	10.9	11.0	8.7	8.7	9.5	10.4	9.4
Secchi (cm):												
Jan	25.4	37.8	26.7	18.9	25.1	13.3	16.4	16.0	26.6	24.5	24	30.1
Feb	21.7	25.4	24.8	16.5	19.2	16.2	16.4	15.0	---	16.3	20.6	27.5
Mar	21.3	16.1	19.0	21.0	18.3	13.8	15.9	14.1	26.1	23.1	17.9	19.6
Apr	16.1	14.0	16.2	17.8	23.6	11.7	16.6	11.6	20.3	16.3	14.3	20.5
May	20.7	14.0	17.4	16.0	17.5	13.3	17.0	18.2	15.1	12.4	14.7	20.8
Jun	14.9	15.8	21.1	13.5	22.8	14.6	14.7	21.7	17.8	12.7	15.3	22.5
Jul	19.0	19.7	22.1	16.1	17.9	12.7	22.2	24.4	14.0	15.9	23.8	27.9
Aug	18.8	23.3	21.2	14.5	23.5	12.7	20.8	25.7	16.1	18.9	26.3	28.4
Sep	25.1	29.2	28.5	16.3	21.9	12.9	25.1	31.5	13.8	21.6	30.6	33.2
Oct	---	36.3	34.6	22.7	23.3	19.6	33.7	38.6	17.1	25.6	27.2	31.8
Nov	27.7	30.7	25.9	25.9	21.9	21.6	25.9	36.1	20.2	28.8	33.6	29.5
Dec	28.1	28.1	25.4	28.0	25.6	20.5	23.2	24.9	21.8	22.3	31.3	27.0

Table 1. 3 continued

	2000	2001
Dissolved Oxygen (mg/l):		
Jan	7.9	9.8
Feb	10.3	9.2
Mar	7.6	8.5
Apr	7.5	8.8
May	7.0	7.7
Jun	7.0	7.2
Jul	7.6	8.2
Aug	7.9	7.9
Sep	7.2	10.8
Oct	7.6	5.6
Nov	8.3	6.2
Dec	8.0	9.7

Table 1. 4 Summary of Suisun Marsh data 1979-1998. Total Fish, Crangon, and Palaemon are average numbers per trawl. Mysids is an abundance index with 5 = most abundant. Salinity (‰), temperature (°C), secchi (cm) and dissolved oxygen (D.O; first recorded in 2000) are yearly averages.

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Total Fish	105.7	49.4	58.1	37.8	34.0	31.2	20.6	29.8	22.7	17.6	24.1
Crangon	7	59	45	40	3	17	6	40	54	27	50
Palaemon	9	15	12	8	3	3	8	5	15	5	10
Mysids	0.3	1.9	1.8	2.5	2.2	2.3	2.2	1.9	1.9	1.8	2.4
Salinity	5.9	2.7	4.3	1.2	0.3	2.1	5.5	2.9	5.8	4.3	4.6
Temp	19.4	16.2	17.1	15.3	16.0	17.4	15.5	16.9	16.0	15.6	17.3
Secchi	---	21.5	23.0	20.1	20.5	26.8	28.6	20.4	25.2	25.8	20.6

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Total Fish	11.8	18.7	20.4	25.2	8.9	23.5	14.9	25.3	17.9	26.1	36.7
Crangon	26	43	11	17	21	49	38	136	24	17	30.6
Palaemon	8	4	3	2	1	2	0	3	3	0	1
Mysids	2.2	1.8	1.2	0.9	0.6	0.8	1.0	1.3	1.2	1.4	1.5
Salinity	6.0	7.1	6.5	2.4	4.3	1.1	2.3	3.6	1.1	2.3	3.2
Temp	16.4	15.5	17.0	17.4	16.6	16.8	16.7	17.1	16.4	15.7	16.2
Secchi	21.6	24.2	23.7	19.0	22.3	15.5	21.5	23.6	18.9	19.9	23.3
D.O.	-	-	-	-	-	-	-	-	-	-	7.9

Table 1.4 continued

	2001
Total Fish	32.3
Crangon	33.2
Palaemon	16.0
Mysids	1.2
Salinity	4.1
Temp	16.0
Secchi	26.8
D.O.	8.5

Table 1.5 Total catch per year for species collected in Suisun Marsh trawls January 1979 - December 2001. See Table 1.1 for species represented by abbreviations.

SPECIES	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
ASH	21	36	156	8	2	5	8	7	7	6	2	16	3	6		4	1	1	1			13	11
BB		3	3	2	1	4	4	2			1					1				1			
BC		2	5	1	1		2	78	7	4							1	3	10	5	127	47	79
BF	2	9	2	4	1																		
BG		5	1	4	1			1									1					1	1
BLB		2	1			11	17	4	1	1						1	4	8	5	17	21	24	15
BLP				10	1	1		1													2		
BYP													1			1							
CC		4		3	1	12	8	5	3	7		1				7	52	2	3	4	19	16	2
CHA													2	1									
CP	214	586	586	171	69	69	257	262	74	46	61	44	61	28	45	35	66	53	202	121	89	77	99
DAB												1		2									
DS	17	168	230	33	11		1			1	1	1	5	3	7	16	2	12		2	26	16	33
FHM		6	2				6	1			1						1		1				
GF	6	23	5	2		21	100	7	3	3	2			1	3	2			1	1	3	16	2
GS																		1		2			
GSF		1	1																1				
GSH									2	1													
HCH		13	24	8	6	6	19	2	10	9		3	1	1		1	2			1			
HH																							1
ISS	10	25	54	6	3	22	128	8	16	22	14	13	18	7	3	15	12	4	7	4	7	6	12
KS		13	19		11	1		13	1	1	1						2	1		1	2	3	2
LFS	14	3244	954	1701	279	553	161	102	110	194	131	242	21	3	3	6	82	8	5	21	1131	393	288
LJM					1																		
MID												2		1	1	4		2					
MQF			4	2		4		1							1	1			2			1	
NAC	2	14	155			1	15	1	6	5	2	2	3	22									27
PH			24	3	2	5	33	1	6	40	1	7	49		1	4	1	25	11	2	3	7	56
PL		1	4					1				1		6			19	1	1	4	1	2	1
PSD																		1					
RS																			1		1		
RT				2			2			1									1				
RWK		3				1				1	3		2							6			
SB	4256	6471	9209	3252	3962	2287	2247	2694	1414	1232	1169	383	1582	2691	1010	792	1481	1517	3047	700	2061	2843	4246
SCP	308	1572	650	639	1176	127	74	376	51	114	41	11	175	137	242	68	674	523	543	397	152	312	18
SF	19	567	236	28	79	20	29	39	15	36	9	14	50	12	6	34	17	39	138	68	20	10	1
SG							2		118	282	1253	819	696	353	117	534	117	48	1202	133	385	140	659
SKG																					1		34
SKR	155	544	610	172	183	99	141	101	68	51	21	21	6	7	18	19	34	63	58	68	51	52	44
SP		2	3						1			11											
SPM	16	44	22	6	3	5	2	9	5	1							2			1		1	
SS		2	2																				
ST	2048	3715	1848	1147	709	192	151	665	442	163	108	80	197	134	62	51	260	438	227	266	388	555	1186
STAG	91	353	366	32	9	40	100	54	18	97	76	52	169	18	14	19	271	51	48	11	36	77	46
STBK	74	2962	5475	949	519	49	53	209	664	69	153	141	581	137	65	48	317	279	339	1275	104	760	80
TFS	35	380	404	87	42	218	37	42	69	20	2	10	5	18	24	17	10	91	20	34	52	57	56
TP	886	1922	2375	1559	175	109	499	602	1278	1275	237	184	189	210	97	158	93	85	251	158	40	56	444
TPS																							
WAK																					1	5	1
WC				6	2	1	3	9	8	3				1	3		9	44		2			
WCF	1	4	4	6	132	32	24	14	6	8		6	2	1	3	6	51	190	79	276	234	331	109
WCK																1							
WM		1																					
WS		4	1	4	8	5		1	3	2			1	1	1	1	4	8	1	4	1	1	3
YFG	173	1157	231	197	23	1004	206	559	278	112	368	145	34	336	3371	174	2176	249	182	284	1591	3427	513
TOTAL	8348	23858	23666	10044	7412	4904	4329	5871	4684	3807	3657	2210	3853	4137	5097	2020	5762	3747	6387	3869	6549	9249	8069
# TRAWLS	79	483	407	266	218	157	210	197	206	216	152	188	206	203	202	228	245	252	252	216	250	252	250
CATCH/TRAWL	106	49.4	58.15	37.76	34	31.2	20.6	29.8	22.7	17.6	24.1	11.8	18.7	20.4	25.2	8.86	23.5	14.9	25.3	17.9	26.2	36.7	32.3

Table 1. 6 Total catch per year for species collected in Suisun Marsh seine hauls from January 1995 - December 2001. See Table 1.1 for species represented by abbreviations.

	1995	1996	1997	1998	1999	2000	2001
ASH			1				1
BB					2	1	
BC				6	2	3	3
BG	1			1			
BF	5						
BLP		1			1		
CC			1	1	4		
CP	3	7	33	33	74	7	8
DS	17	2	1	1	1	5	1
FHM	1	3	6	3	3		
GF		1		1	4	3	
GSH				1			
HCH	1			1	1		
ISS	1827	1991	4794	1091	1670	3053	4284
KS	48	6	1	4	14	4	8
LFS	2				2	1	1
LMB				1			
MQF	18	19	35	24	30	2	1
PH		1	4		5	9	4
RT		1			1		1
RWK	6	1	1	1		1	3
SB	203	492	1906	90	376	480	506
SCP	38	21	16	8	6	25	1
SF	4	18	23	2		2	
SG	170	43	274	106	33	64	122
SKR	3	6	8	1	5	2	1
SPM	11	2	9	7	1	1	3
ST	246	99	107	153	446	207	120
STAG	373	92	146	63	310	260	213
STBK	130	195	99	44	54	48	95
TFS	203	415	144	340	210	85	166
TP	95	41	27	100	13	19	17
WAK			1			3	
WCF		3	3	43	21	2	12
YFG	2075	909	611	770	1977	2288	708
Total	5480	4369	8251	2896	5266	6575	6279
Number of siene hauls	72	84	84	74	84	84	84
Mean fish per haul	76.1	52.0	98.2	39.1	62.7	78.3	74.8

Figures

Figure 1.1. Suisun Marsh site map.

Figure 1.2. Locations of historic sampling sites in Suisun Marsh.

Figure 1.3. Locations of current sampling sites in Suisun Marsh.

Figure 1.4. Average daily delta outflow measured at Chipps Island for water year 2000 and 2001.

Figure 1.5. Mean catch per trawl of native and introduced fishes in Suisun Marsh.

Figure 1.6. Mean catch per trawl of striped bass (SB) in Suisun Marsh.

Figure 1.7. Mean catch per trawl of yellowfin goby (YFG), shimofuri goby (SG) and shokihaze goby (SKG) in Suisun Marsh.

Figure 1.8. Mean catch per trawl of splittail in Suisun Marsh.

Figure 1.9. Mean catch per trawl of delta smelt (DS) and longfin smelt (LFS) in Suisun Marsh.

Figure 1.10. Mean catch per trawl of tule perch (TP) in Suisun Marsh.

Figure 1.11. Mean catch per trawl of prickly sculpin (SCP), Sacramento sucker (SKR), and Pacific staghorn sculpin (STAG) in Suisun Marsh.

Figure 1.12. Mean catch per trawl by slough in Suisun Marsh.

Figure 1.13. Mean catch per trawl of *Crangon franciscorum* and *Palaemon macrodactylus* in Suisun Marsh.

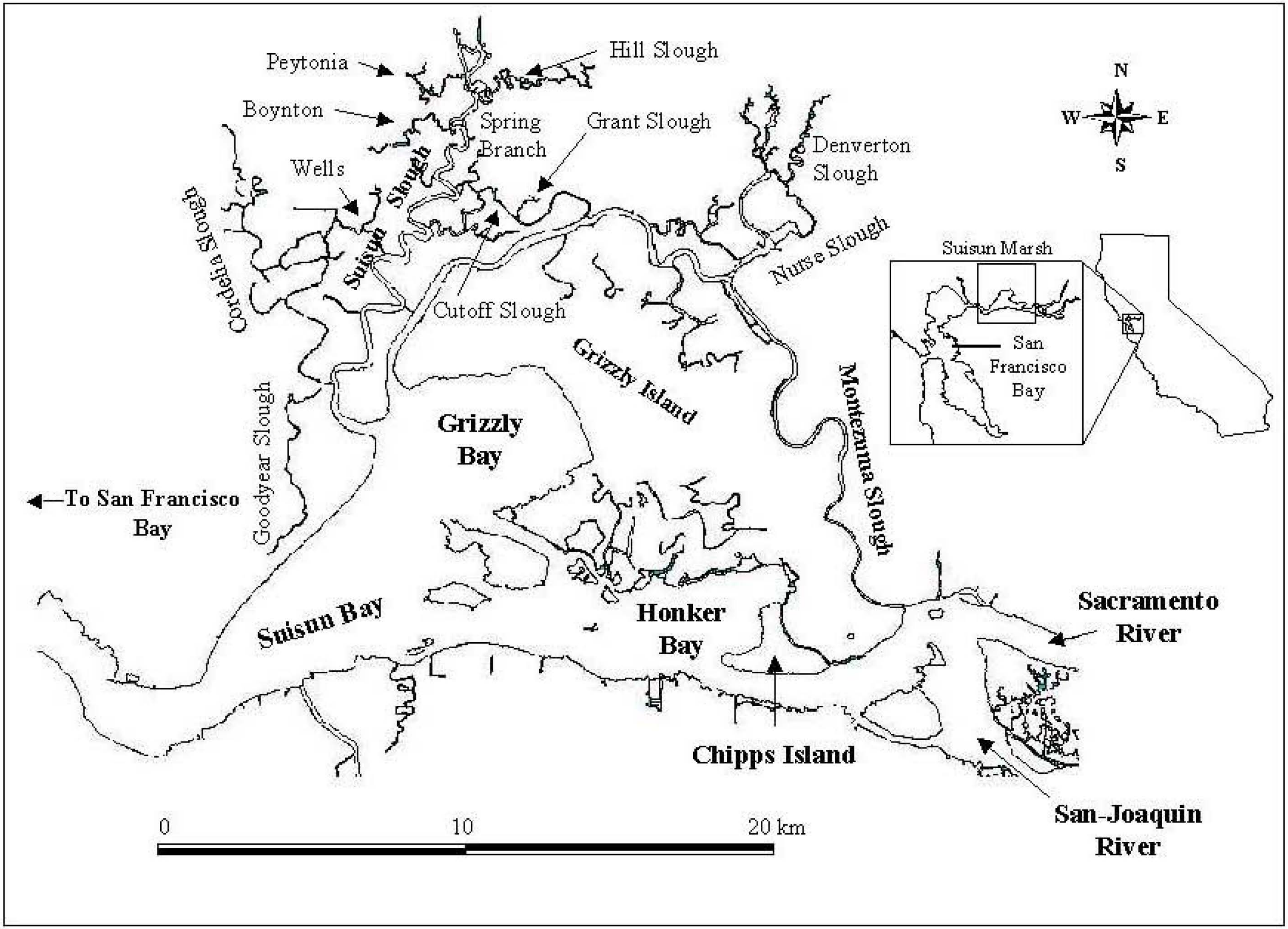
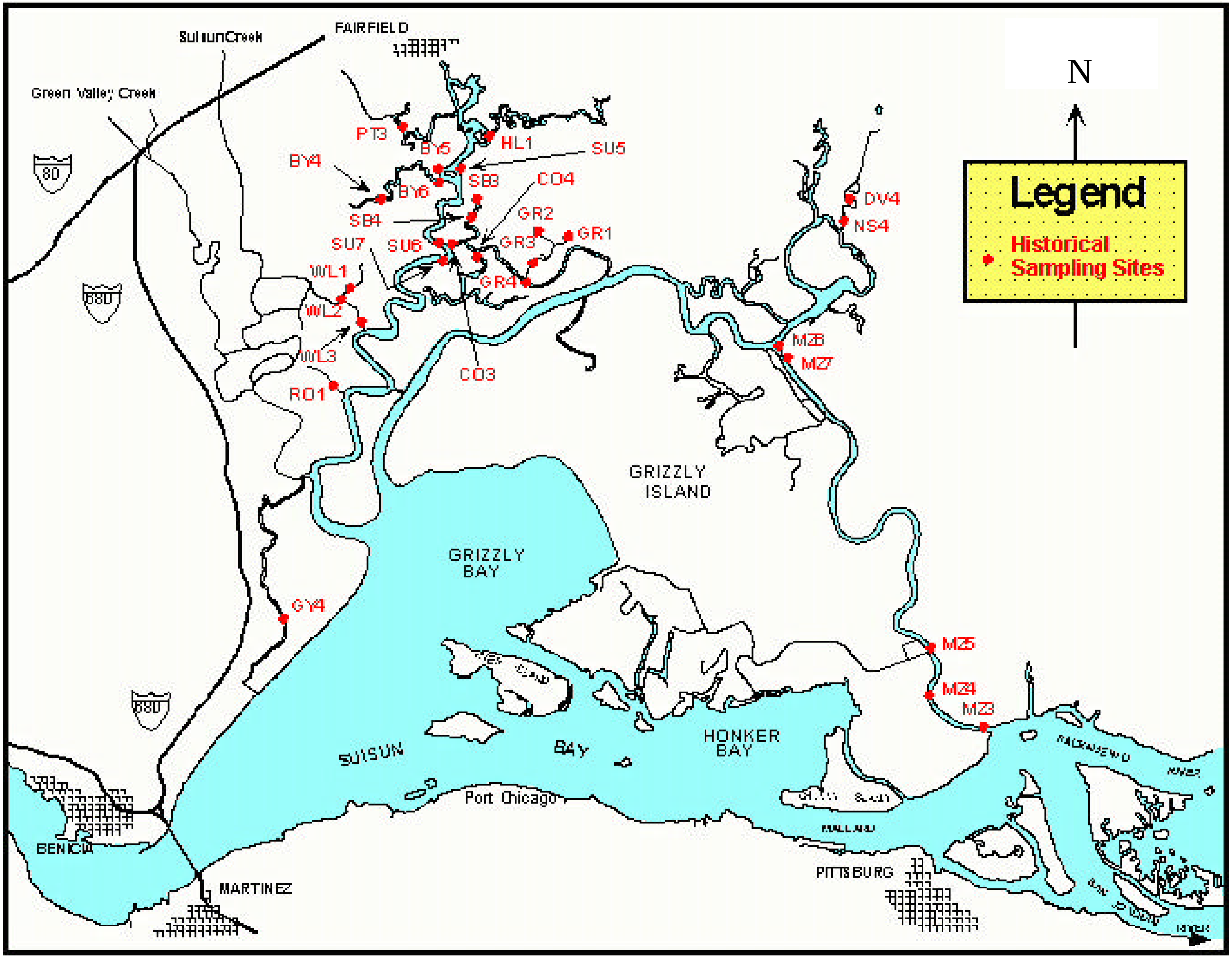
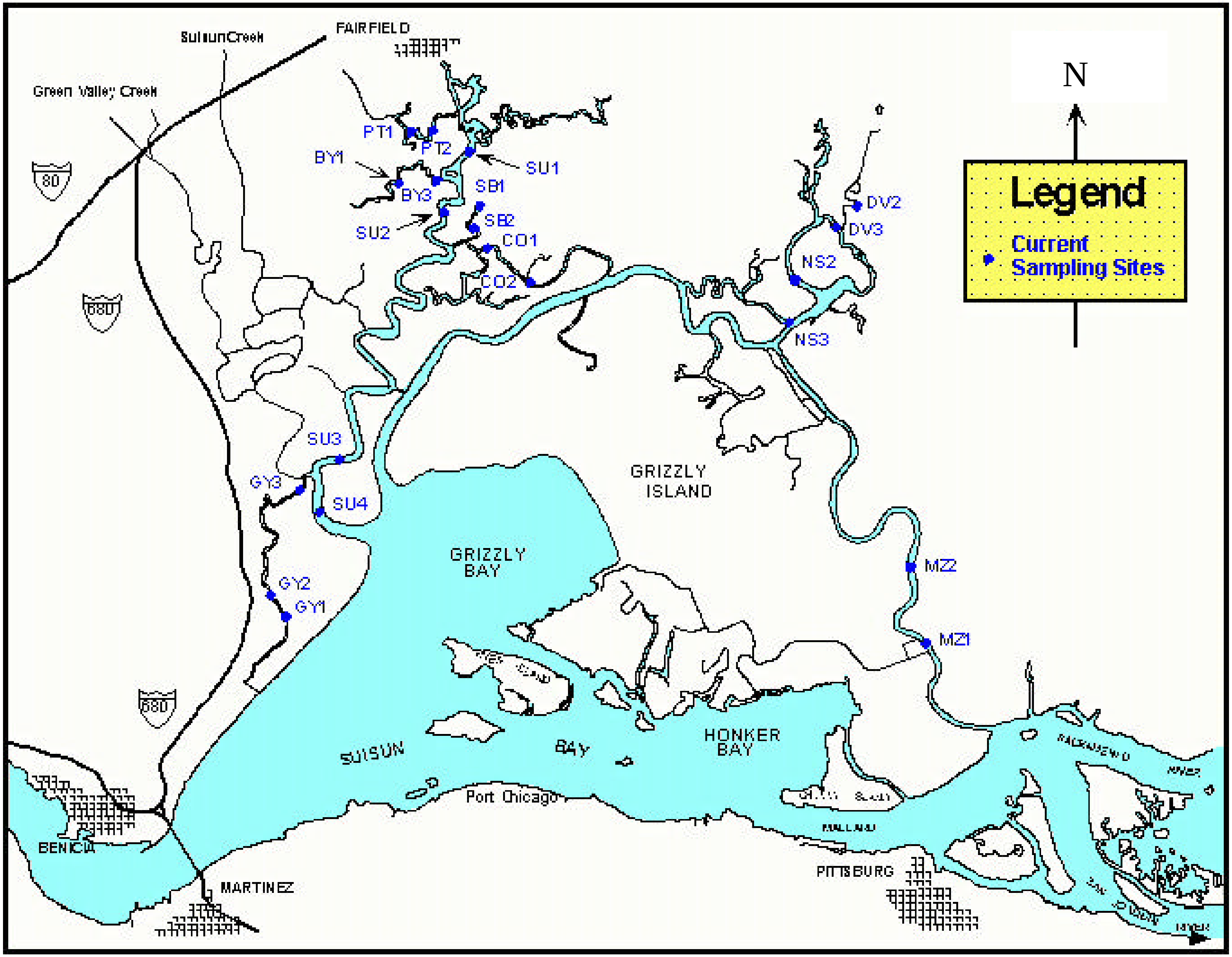

Peytonia
Hill Slough
Boynton
Spring Branch
Grant Slough
Denverton Slough
Wells
Suisun Slough
Cordelia Slough
Nurse Slough
Suisun Marsh
Cutoff Slough
San Francisco Bay
Grizzly Island
Montezuma Slough
Grizzly Bay
Goodyear Slough
To San Francisco Bay
Suisun Bay
Honker Bay
Sacramento River
Chipps Island
San-Joaquin River
0
10
20 km
N
W
E
S

Figure 1.1



FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
680
N
Legend
Historical Sampling Sites
PT3
BY5
HL1
SU5
BY4
SB3
CO4
BY6
SB4
GR2
GR1
SU7
SU6
GR3
WL1
GR4
WL2
WL3
CO3
RO1
DV4
NS4
MZ8
MZ7
GRIZZLY ISLAND
GRIZZLY BAY
GY4
MZ5
MZ4
MZ3
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG

Figure 1.2



FAIRFIELD
SuisunCreek
Green Valley Creek
80
680
680
N
Legend
Current Sampling Sites
PT1
PT2
BY1
BY3
SU1
SB1
SB2
SU2
CO1
CO2
DV2
DV3
NS2
NS3
SU3
GY3
SU4
GY2
GY1
MZ2
MZ1
GRIZZLY ISLAND
GRIZZLY BAY
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG

Figure 1.3

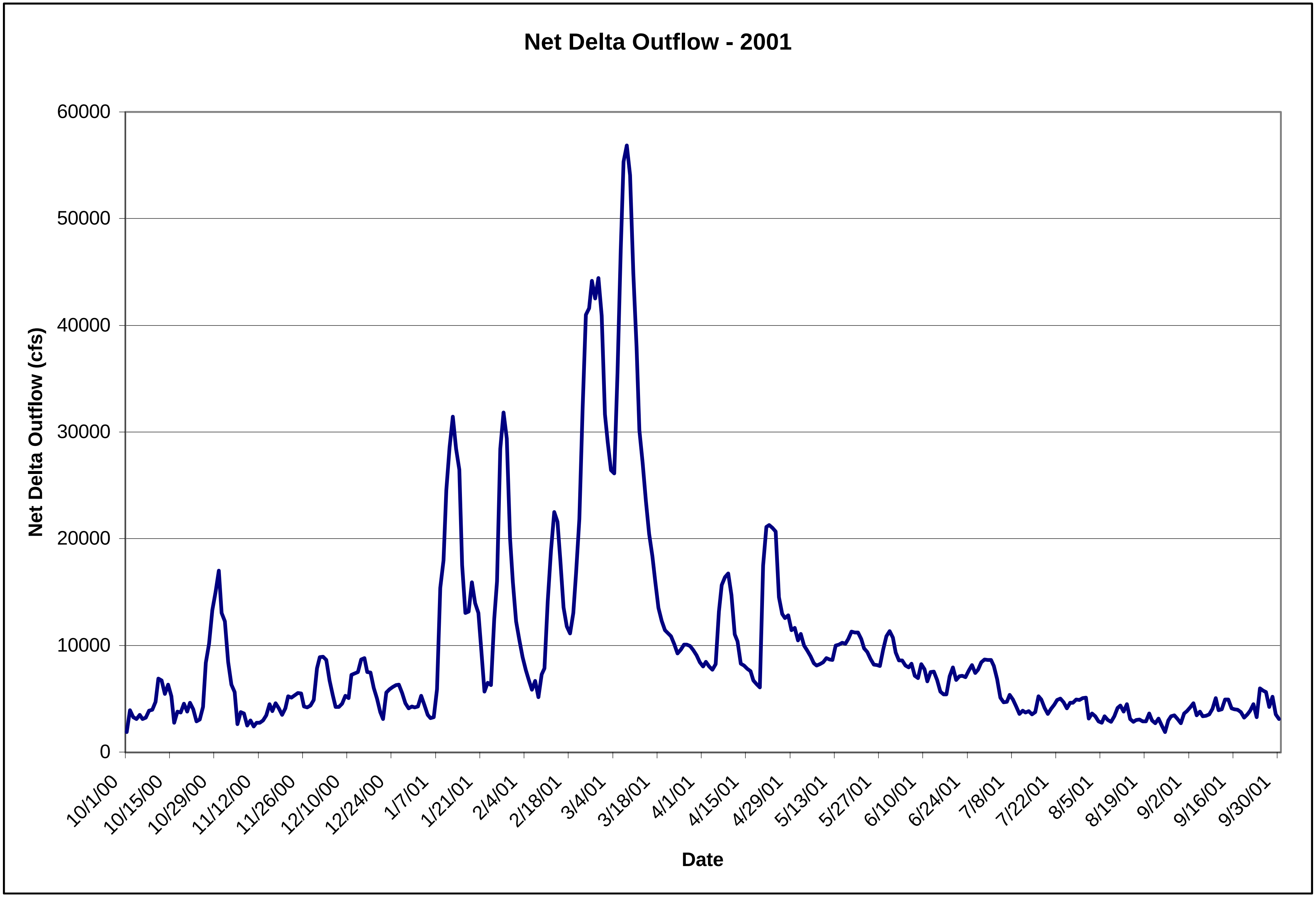

Net Delta Outflow - 2001
Net Delta Outflow (cfs)
60000
50000
40000
30000
20000
10000
0
10/1/00
10/15/00
10/29/00
11/12/00
11/26/00
12/10/00
12/24/00
1/7/01
1/21/01
2/4/01
2/18/01
3/4/01
3/18/01
4/1/01
4/15/01
4/29/01
5/13/01
5/27/01
6/10/01
6/24/01
7/8/01
7/22/01
8/5/01
8/19/01
9/2/01
9/16/01
9/30/01
Date

Figure 1.4

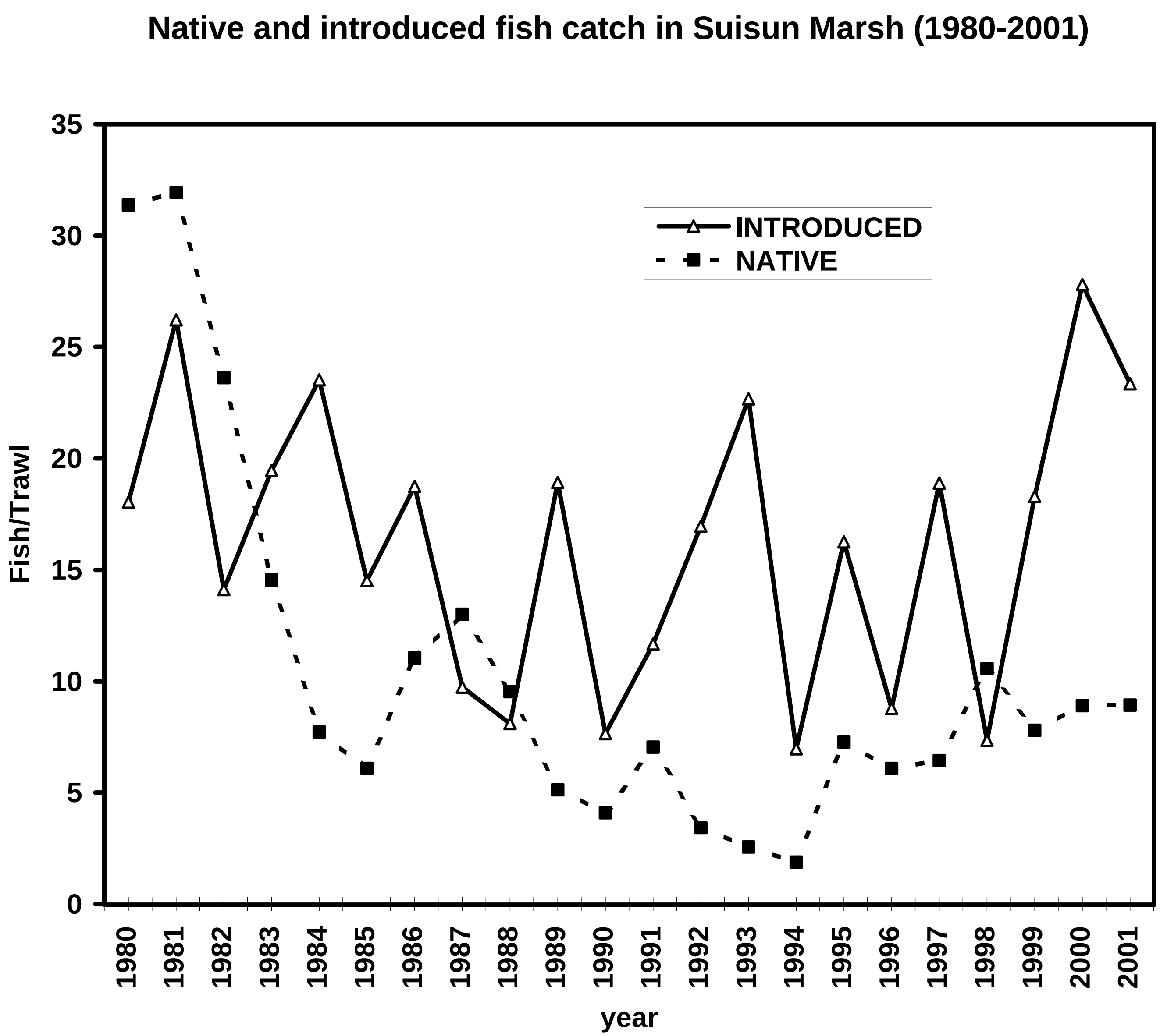

Native and introduced fish catch in Suisun Marsh (1980-2001)
INTRODUCED
NATIVE
Fish/Trawl
0
5
10
15
20
25
30
35
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
year

Figure 1.5

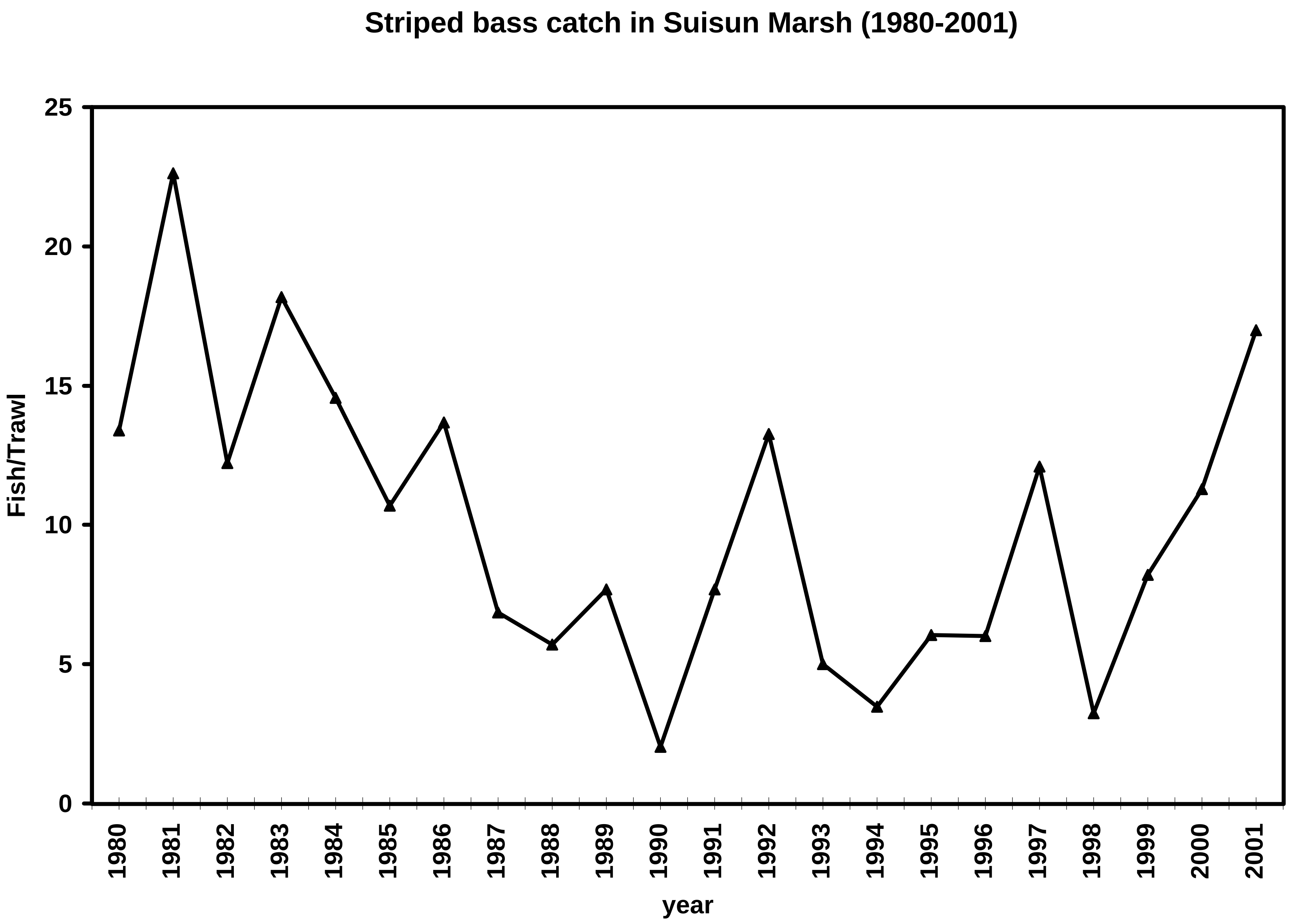
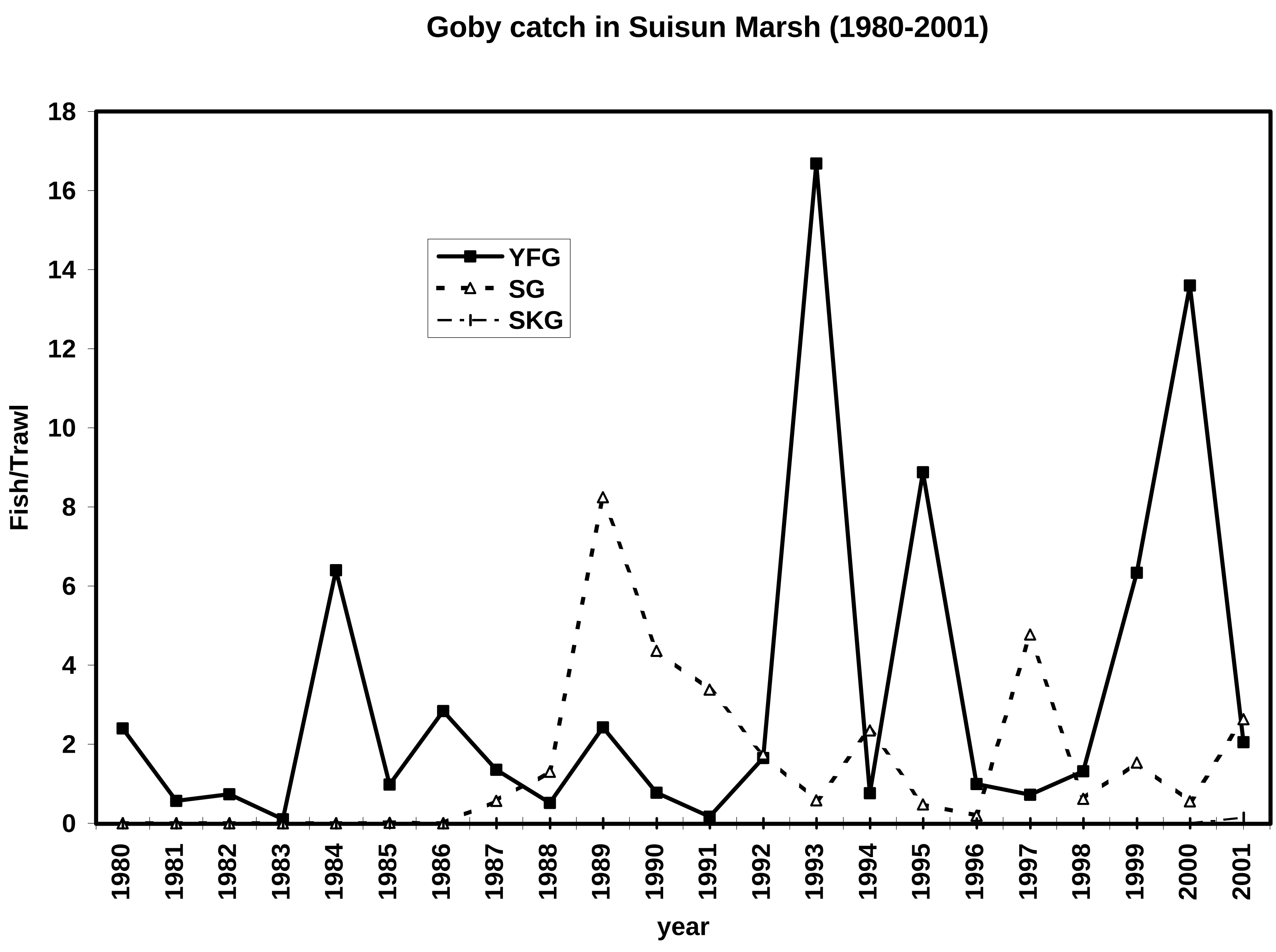

Striped bass catch in Suisun Marsh (1980-2001)
Fish/Trawl
0
5
10
15
20
25
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
year

Figure 1.6



Goby catch in Suisun Marsh (1980-2001)
YFG
SG
SKG
Fish/Trawl
0
2
4
6
8
10
12
14
16
18
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
year

Figure 1.7

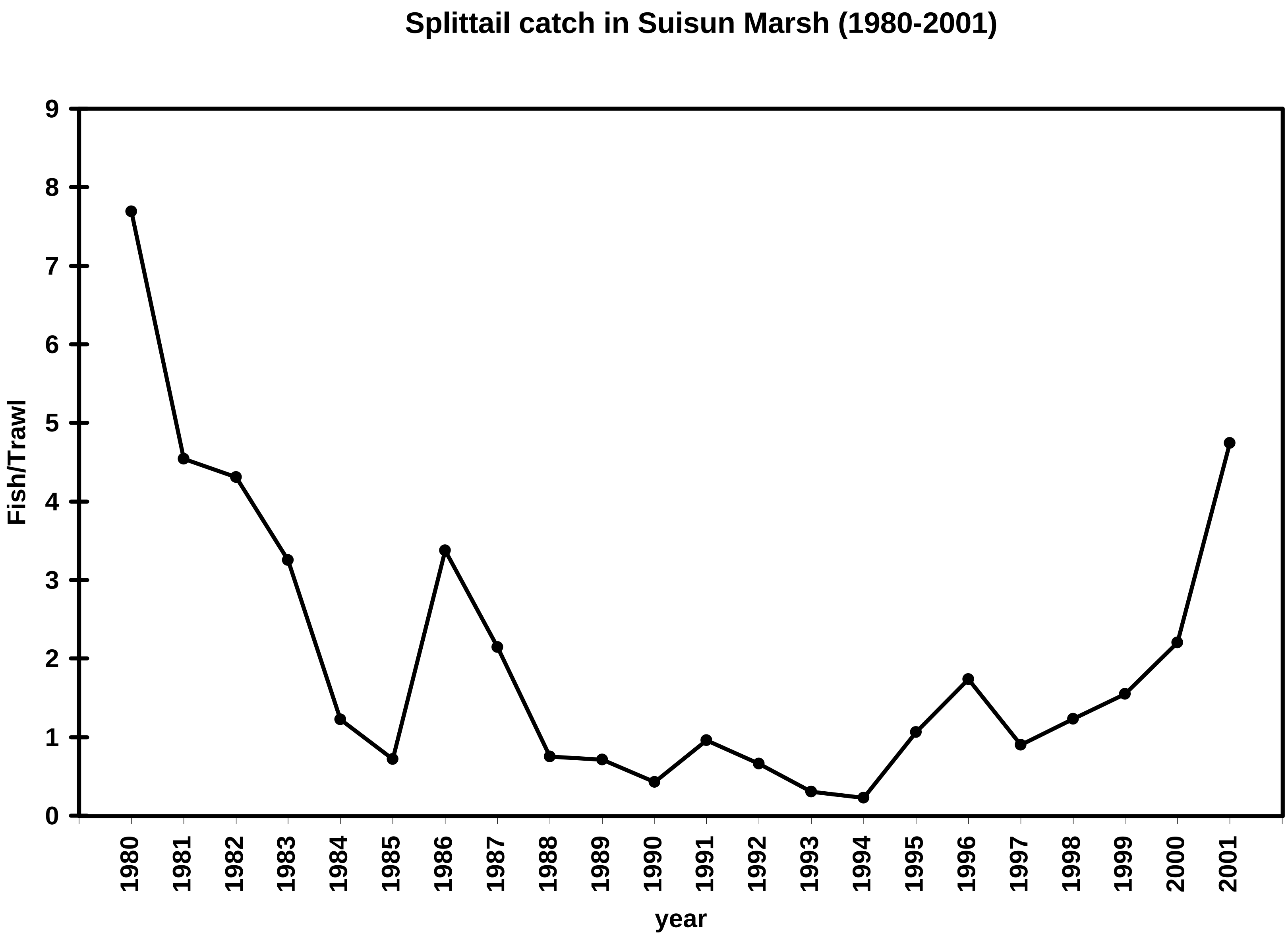

Splittail catch in Suisun Marsh (1980-2001)
Fish/Trawl
0
1
2
3
4
5
6
7
8
9
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
year

Figure 1.8

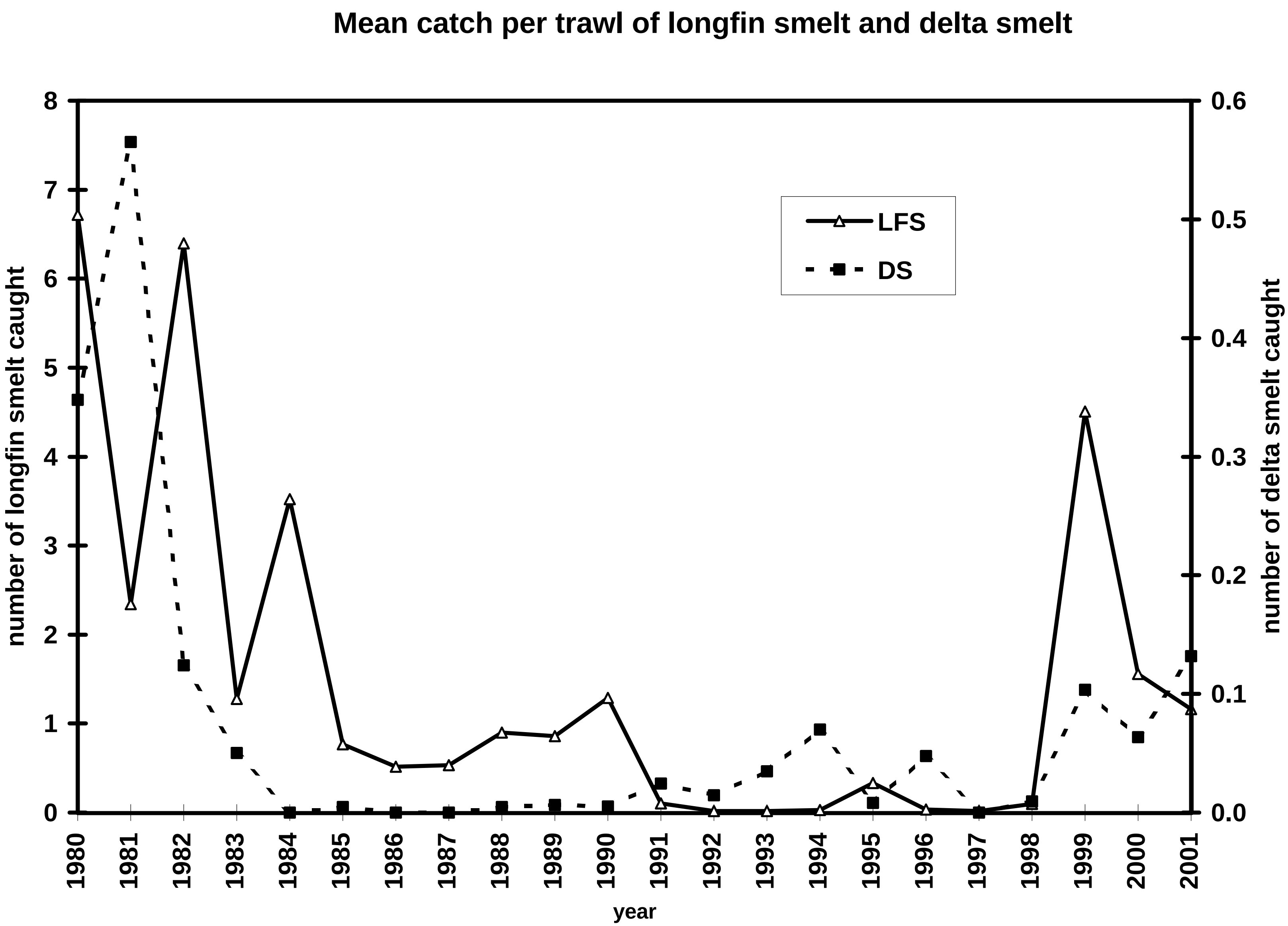

Mean catch per trawl of longfin smelt and delta smelt
LFS
DS
number of longfin smelt caught
number of delta smelt caught
year
0
1
2
3
4
5
6
7
8
0.0
0.1
0.2
0.3
0.4
0.5
0.6
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001

Figure 1.9

Tule perch catch in Suisun Marsh (1980-2001)

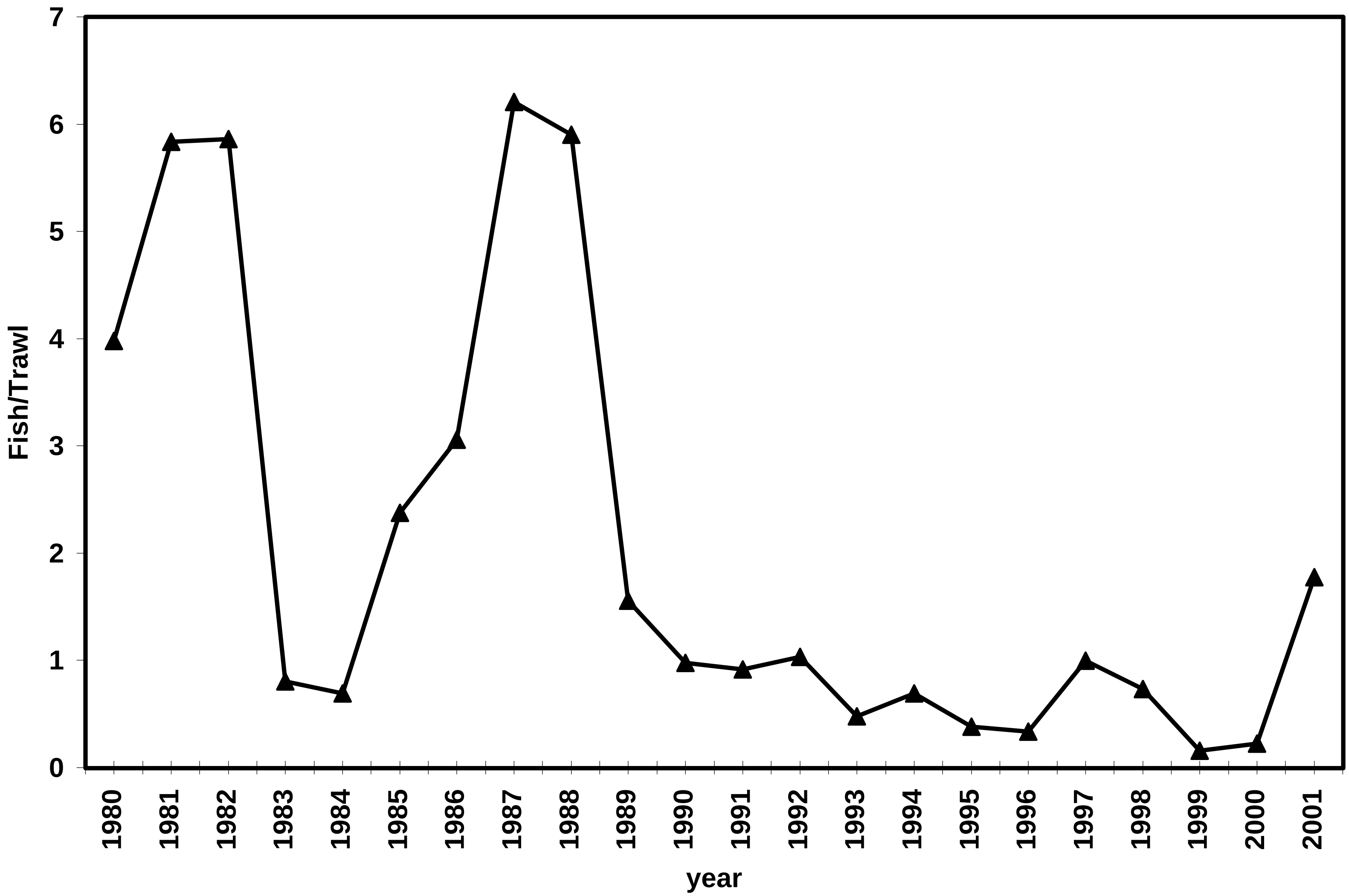
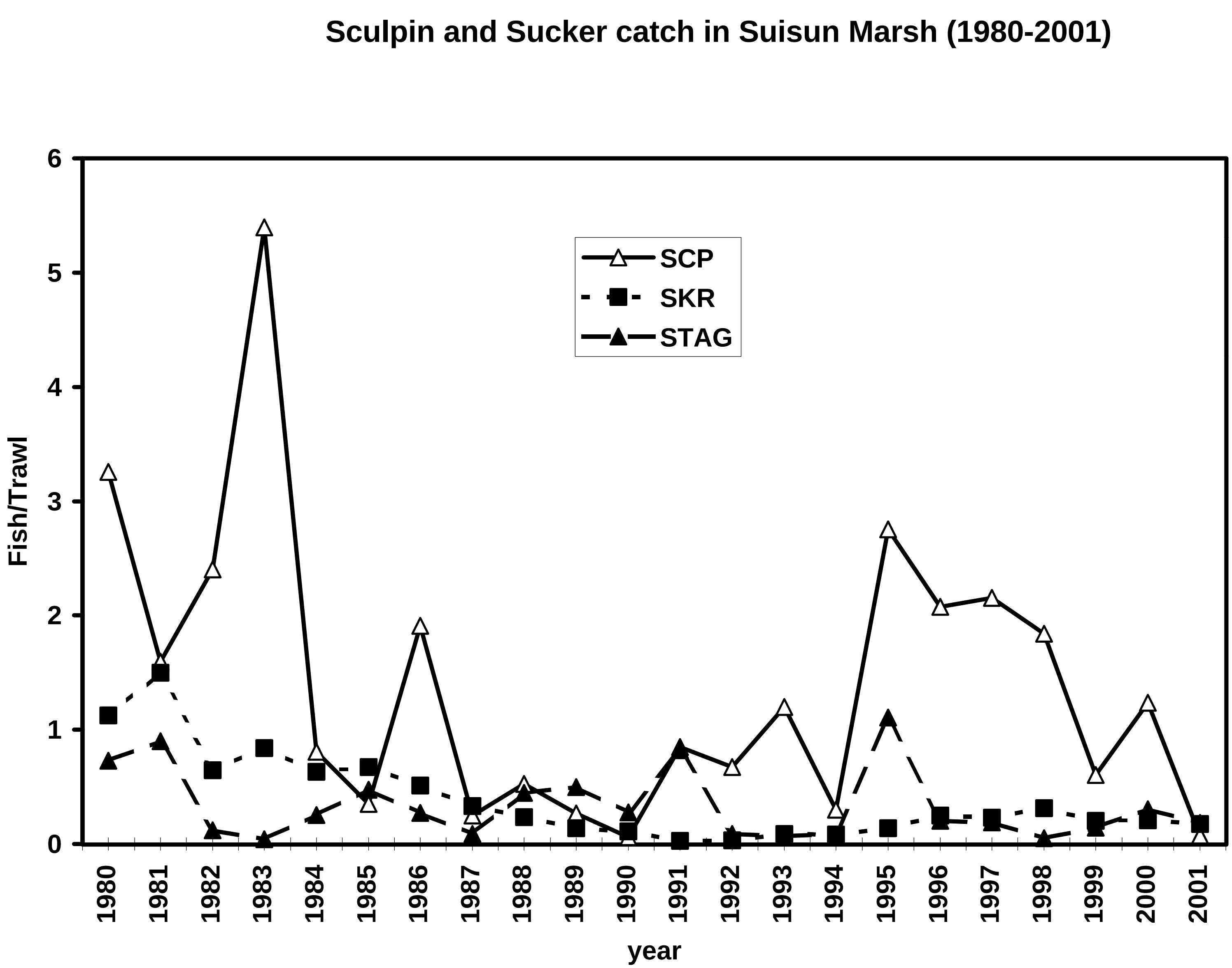


Figure 1.10



Sculpin and Sucker catch in Suisun Marsh (1980-2001)
SCP
SKR
STAG
Fish/Trawl
0
1
2
3
4
5
6
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
year

Figure 1.11

Fish catch per trawl (all species) by slough listed in order of increasing abundance

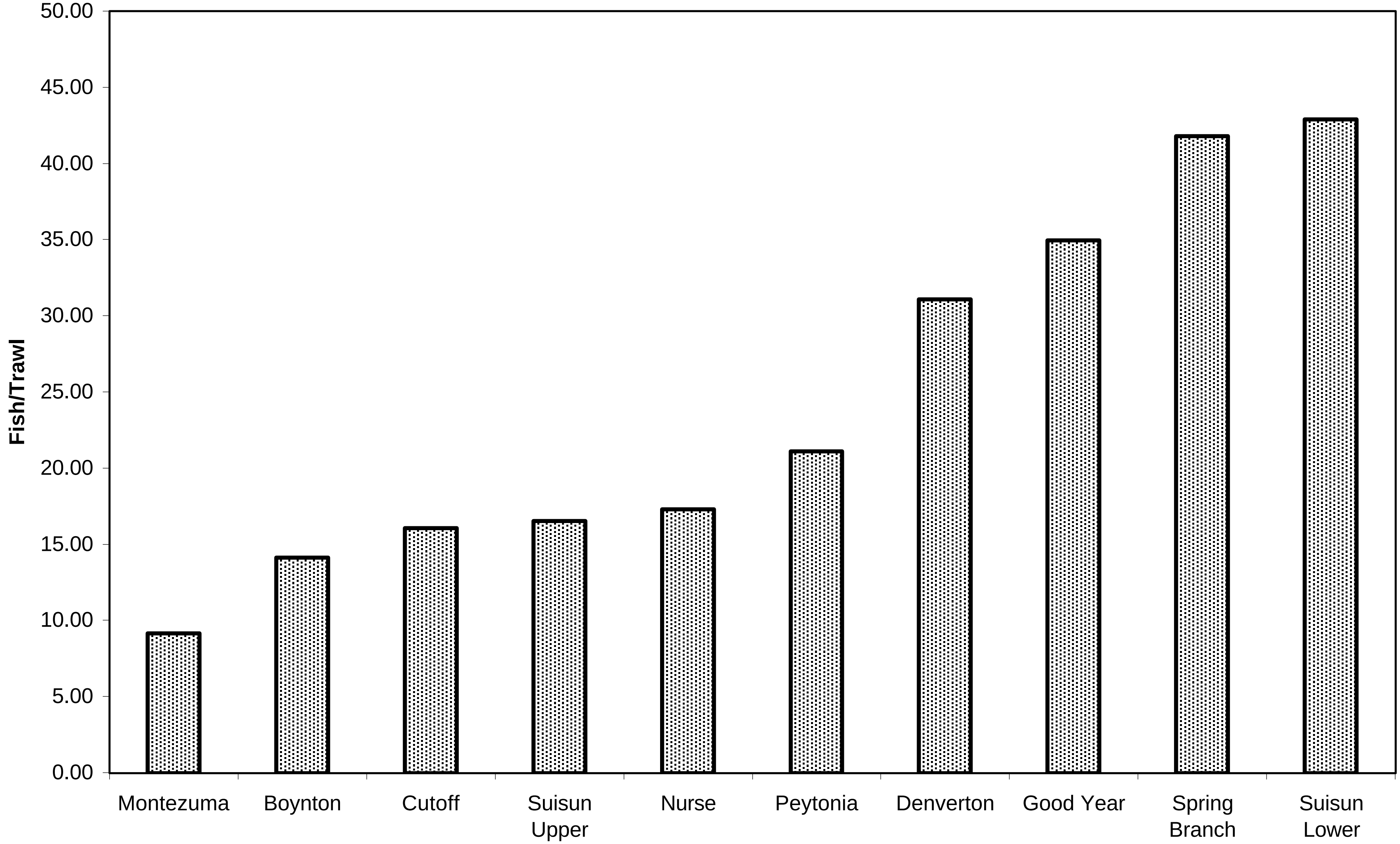


Figure 1.12

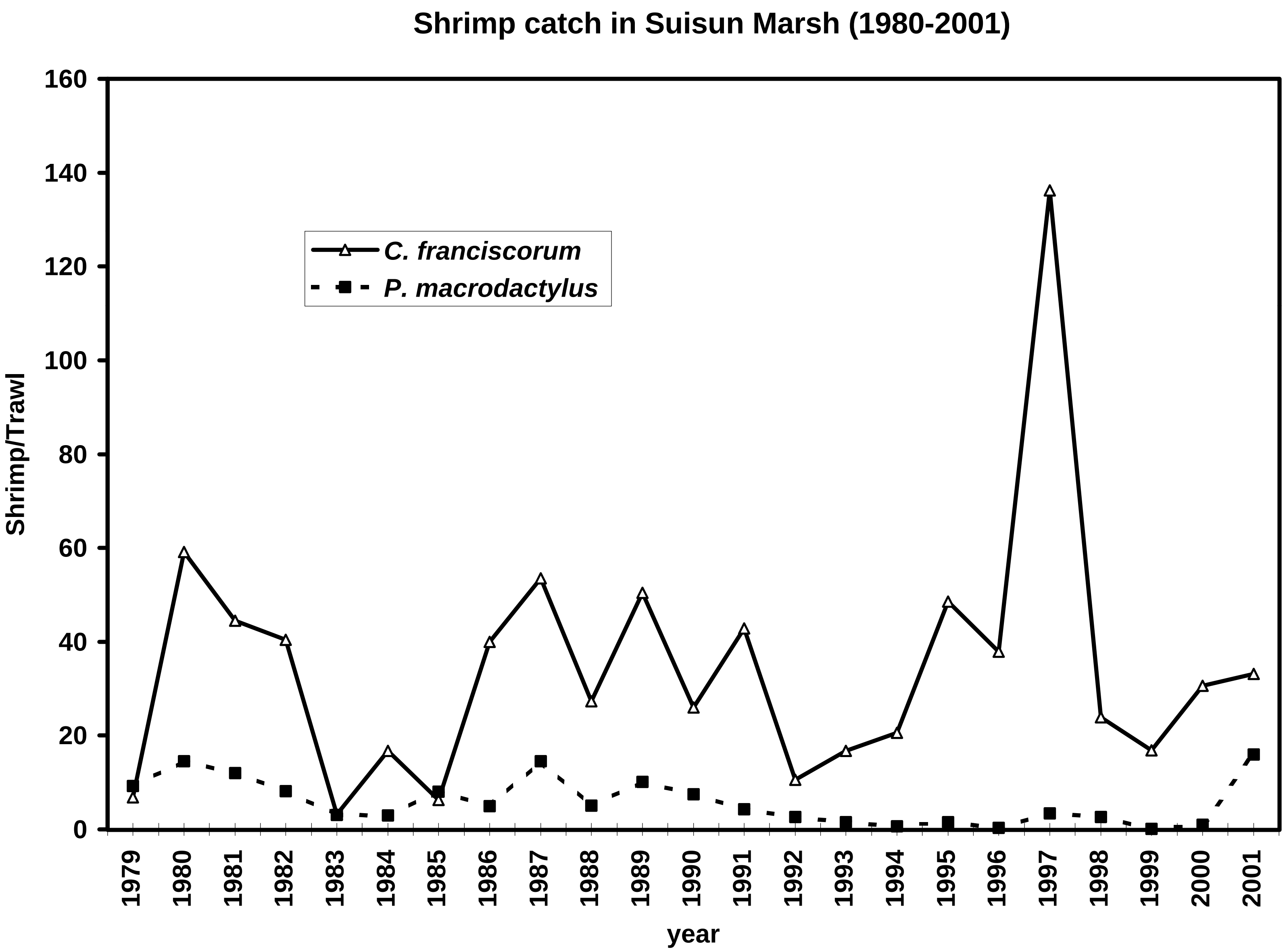

Shrimp catch in Suisun Marsh (1980-2001)
160
140
120
100
80
60
40
20
0
Shrimp/Trawl
C. franciscorum
P. macrodactylus
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
year

Figure 1.13

Part 2: Suisun Marsh Larval Fish Survey
February 1 – June 12, 2001

Introduction

Prompted by the observed decline and low abundance of several of the native estuarine-dependent fish species of the Sacramento-San Joaquin Delta and a general lack of understanding of their various life history stages, an investigation of the use and importance of Suisun Marsh for fish spawning and rearing was initiated by UCD in April of 1994. The goals of the Suisun Marsh larval fish study are: (1) to augment our understanding of adult fish communities of the marsh with information on multiple fish life history stages; (2) to determine the extent the relatively undisturbed habitat of the marsh is used by fish for spawning and rearing; and (3) to determine if special status species such as delta smelt, longfin smelt, and splittail are using the marsh for spawning and rearing. This section of the report (Part 2) presents the findings from the eighth year (2001) of the Suisun Marsh larval fish study.

Methods

Larval fish in Suisun Marsh were sampled weekly from February 1 to June 12, 2001 with a 505-micron mesh net (3 m long with a 0.362 m^2 mouth opening) mounted on a sled. Five sloughs were sampled with three replicate, 5-minute tows in each slough: Suisun, Spring Branch (upper marsh), Nurse, Denverton (eastern marsh), and Cordelia (western marsh). Sampling sites are shown in Figure 2.1. Generally, the western marsh, farthest downstream, is the most saline, the eastern marsh, closest to the Sacramento River has the lowest salinities, and the upper marsh, fed by small streams, has intermediate salinities. A flow meter was attached to the larval fish sampling sled and samples were adjusted for the amount of water that passed through the net. In 2001, the volume of water passing through the net averaged 108 cm^3/s and ranged from 65-154 cm^3/s. For each site the tidal stage, temperature (°C), salinity (‰), specific conductance (µS), and water transparency (secchi depth in cm) were recorded.

Larval fish samples were preserved in 5% formalin solution tinted with rose bengal to aid fish identification. The total number of fish in each sample was counted unless samples were very large. If a jar contained more than 1000 larvae, total number of fish was estimated to the nearest 100. When more than 400 fish were caught in a replicate, only 200 were identified by random subsampling. In samples containing more than 400 fish, the number of fish within each species-family group was adjusted for extra fish in the sample by multiplying number of fish in each species-family group by the sum of total fish identified and extra fish divided by total fish identified [i.e. ((total fish identified + extra fish)/total fish identified) multiplied by number of fish identified in each species-family group]. Johnson Wang identified fish to species or family.

Results

During the 2001 sampling season, 45,470 fish larvae from 11 families were captured in 283 trawls. A total of 21 species were present in the samples (Table 2.2 and 2.3). In total, 9 introduced species were captured making up 63.9% (29,034) of the total larval fish catch.

Twelve native species made up the remaining 36.1% of the catch with a total of 16,436 individuals.

Larval fish diversity in 2001 was high relative to previous sampling years (1994-2000). Larval fish catch in May yielded the greatest number of species (16 species; Table 2.1, Figure 2.2). A range of 9-11 species was observed in the February and March samples, whereas 12 - 16 species were captured in April and May. Greatest diversity in catch on a per slough basis occurred in Cordelia (16 species), Nurse (13 species) and Suisun (13 species) sloughs (Figure 2.3 and Table 2.2). Denverton Slough had the lowest catch with only 9 species (Figure 2.3 and Table 2.2). Numerous marine species such as northern anchovy, Pacific herring, cheekspot goby, longjaw mudsucker and jacksmelt were captured in 2001 contributing to the overall high catch of species. Cheekspot goby and jacksmelt (only one specimen collected) were captured in Suisun Marsh for the first time in 2001.

The abundance of larval fish was greatest in May and June 2001, due mainly to the very high abundance of shimofuri goby and also the high catch of striped bass (Table 2.3). As in past years, there were two distinct peaks in total larval fish abundance over the sampling period, which was due to the seasonality of two distinct spawning groups (Figure 2.2). The first group was comprised mostly of native species such as prickly sculpin, longfin smelt and Pacific herring and they were most abundant in February and March. The second group, made up primarily of introduced species (shimofuri goby, striped bass, threadfin shad and inland silverside) and typically more marine oriented native species (northern anchovy and cheekspot goby) was most abundant in May and June.

Overall shimofuri goby was the most abundant species comprising 56 % (11,629 individuals) of the total (February – June) larval fish catch. Prickly sculpin was the second most abundant species comprising 25.6% of the total catch. Longfin smelt and striped bass were the next most abundant species comprising 8.8 % and 7.3 % of the total catch, respectively. All other species were rare, collectively comprising less than 2.5% of the total larval fish catch (Figure 2.2; Table 2.2).

<u>Catch of Special Status Species</u>

A total of 4048 longfin smelt were captured in 2001, with their greatest catch occurring in February and March (Figure 2.4), although they were captured in all months sampled except June (Figure 2.4 and Tables 2.3 and 2.4). Longfin smelt were captured in all sampled sloughs (Table 2.2 and Figure 2.5), but they were most abundant in Cordelia Slough (3050 indiv.) followed by Nurse Slough (347 indiv.).

A total of 33 delta smelt larvae were captured in 2001, down from 122 in 2000. Delta smelt larvae were captured between February and May 2001 (Figure 2.4 and Tables 2.3 and 2.4), but were most abundant in May. Delta smelt were captured in all sampled sloughs with the exception of Spring Branch, but they were most abundant in Nurse Slough (17 indiv), as they have been in the last few years (Table 2.2 and Figure 2.5). Only 2 wakasagi larvae were captured in the 2001 sampling season. The wakasagi larvae were captured in May, the month of greatest delta smelt abundance. Only 1 splittail larvae was captured in 2001 in Nurse Slough.

Water Year and Environmental Conditions

The California Department of Water Resources (CDWR - DAYFLOW) classified 2001 as a "Dry" water year (Table 2.5) with net delta outflow from February 1 through June 30 (2,166,759 cfs) being less than half that of the next closest year, 1997 (5,425,310 cfs). Although flow conditions were most similar to the 1997 outflow year, environmental conditions in 2001 were most similar to those observed in 1995 in terms of water temperature patterns and 1994 and 1997 in terms of salinity. Salinities fluctuated between averages of 0.6 to 4.6 ‰ from February to June 12, 2001. Salinity was highest in Cordelia in June (4.6 ‰) and lowest in Nurse Slough in April (0.6 ‰) (Table 2.1). Average temperatures for all months sampled ranged from 9.2 – 21.5 ^{o} C, with highest temperatures in Denverton in June and lowest temperatures in Nurse Slough in February (Table 2.1). Mean water clarity ranged from 16.6 cm to 31.5 cm (Table 2.1).

Discussion

Numerous factors are likely influencing the observed variability in larval fish diversity and abundance. Some of this variability may be attributed to the timing and frequency of sampling and the corresponding environmental conditions (Meng and Matern 2001). The observed switch in dominance, as measured by abundance, of various species of larval fish over the duration of the survey (e.g. high goby abundance in dry years and later in the season and occasional high abundance of sculpin) indicates that time of sampling and environmental conditions can have large effects on catch of larval fish species. For instance, sculpin and longfin smelt generally dominate the larval fish catch in Suisun Marsh in February and March, whereas they are almost entirely replaced by shimofuri goby and striped bass in May and June. Water temperatures appear to be one of the primary factors driving the total catch and also the catch of specific species within Suisun Marsh, as pointed out by Meng and Matern (2001). In 2001, the rapid increase in water temperatures in May and June likely contributed to the observed decline in native species abundance and the dramatic increase in catch of shimofuri goby. This same pattern has also been observed in other years, most notably 1995 and 1997, with some variation in catch due to the temperature and degree of outflow in any given year.

Water year and Environmental Conditions

Of the eight years larval fish have been sampled in Suisun Marsh, five were classified as wet, one as above normal, one as dry and one as critical (Table 2.5). Total catch during these highly variable water years has fluctuated considerably. However, some predictable trends have emerged. For instance, the highest total catch usually occurs in low to moderate outflow years (Table 2.5) such as in 1994, 1997 and 2001 or under high outflow conditions when water temperatures are fairly warm in the middle of the sampling period (Table 1.3; i.e. April 1995). This is largely due to a strong response by introduced species such as the shimofuri goby and striped bass to the warm water conditions. High outflow conditions, such as in 1995, 1996 and 1998 have had less of a predictable effect, perhaps due to the variability in timing of discharge or due to variation in the resulting environmental conditions. Overall, total larval fish abundance is typically low under high outflow conditions, perhaps due to system flushing (nutrients, sediments etc.) and the vulnerability of larval fish to high flow conditions, but also due to lower and more consistent temperatures over the sampling period (February – June).

Diversity patterns in our Suisun Marsh larval fish catch appear to be related primarily to the precipitation within any given year. Drier conditions often result in increased abundance of marine larvae in the marsh and increased diversity, particularly at the western end of the marsh (Cordelia Slough). For example, northern anchovy, Pacific herring, cheekspot goby, and jacksmelt, all generally found in higher salinity waters, were captured in the "dry" water year of 2001. This is most likely a reflection of increased salinity associated with decreased outflow. Conversely, in years with high precipitation and outflow, there is generally increased spawning in the upper marsh by characteristically freshwater species and ultimately greater transport of their larvae into our sampling areas due to high flow conditions. The catch of larval Sacramento sucker, bigscale logperch, wakasagi and centrarchids in the upper marsh between 1998 and 2000 is consistent with these observations.

Catch of Special Status Species

Catches of special status species over the course of the larval fish-sampling project have reflected differences in outflows. The best year for delta smelt was 1996 (954 individuals; Table 2.6, Figure 2.6). Officially, 1996 was considered a wet year, but with intermediate flows compared to 1995 and 1998. Catch of delta smelt in 1999 (99 indiv.) and 2000 (122 indiv.) was 10 % and 13 %, respectively, of the catch in 1996, which is still the second and third highest catch of delta smelt larvae recorded during the larval fish study (Table 2.6, Figure 2.6). Thus the moderate outflow years of 1999 and 2000 may also have been favorable for delta smelt. Catch of delta smelt declined considerably in 2001 to only 33 individuals, most likely due to the spawning populations moving further upstream due to the low outflow and resultant higher salinities. Of all the estuarine-dependent species, delta smelt seem to have the narrowest tolerance for variability in outflow (Moyle et al. 1992). When flows are too high they may be washed away from their preferred rearing grounds in Suisun Bay. Low flows may position them up in the river where nursery conditions are not as favorable, as they likely did in 2001.

The abundance of larval longfin smelt in 2001 (4048 individuals) was the highest recorded since sampling began in 1994 and it more than doubles the previous high catch in 2000 (1700 individuals). The presence of large numbers of longfin smelt in our samples by the first week of February, as has been observed in prior years, suggests that we may not have sampled the entire larval production period, which may have begun as early as middle to late January. This is in agreement with the catch of large (50 – 100 mm) longfin smelt in our otter trawls between November 2000 and February 2001. The protracted catch of longfin smelt larvae from February to May, also suggests that spawning occurred over an extended period of time in 2001, as it did in 2000. Similarly to delta smelt, it appears as if longfin smelt respond positively to low to moderate outflow conditions, which were present in 1996, 1997, 1999, 2000, and 2001. However, they may be more tolerant than delta smelt to periods of higher salinities often associated with these low to moderate outflow years. Very high flows may either wash them out of the upper estuary or simply decrease catch efficiency.

The observed distributions of larval longfin and delta smelt in Suisun Marsh have remained constant across the sampled years. Longfin smelt are typically captured in greatest abundance adjacent to high salinity areas such as in Cordelia Slough. This finding lends support to the possibility that the high abundance of longfin smelt in Cordelia Slough may be due to local spawning either in Cordelia Slough or adjacent to it. Alternatively, it is also possible that the circulation of water through Grizzly Bay and into Suisun Marsh via lower Suisun Slough could also be pushing longfin smelt larvae into the marsh along with tidal flows. An interesting finding in the 2001 larval longfin smelt catch, is that no longfin smelt were captured in Cordelia Slough the first week of fish collections (February 1, 2001) despite their presence in low numbers at all of the other sampled stations.

Delta smelt larvae are typically captured in greatest abundance near areas of freshwater inflow such as in Denverton and Nurse sloughs, which are the closest sites to the Sacramento River. Adult smelt have been captured in Nurse Slough around the time of potential spawning making it possible that some local spawning might be taking place. The presence of nonnative wakasagi in Suisun Marsh (50 in 1998, 5 in 1999, 32 in 2000 and 2 in 2001) at the same time as larval delta smelt, is of concern. Wakasagi may potentially be impacting delta smelt through a number of mechanisms including (1) mating interference (loss of mating opportunity due to heterospecific mating); (2) hybridization (but see Stanley et al. 1995); and (3) competition for limiting resources including food.

A single splittail larvae was captured in our 2001 sampling suggesting that, as in past years, very limited spawning occurred within Suisun Marsh or the areas adjacent to Suisun Marsh.

Conclusions

The exceptional low outflow in 2001 ("Dry" water year designation DWR) marks the first time in the past 7 years that outflow over the February – June time period has been below 5,000,000 cfs. In fact the outflow in 2001 (2,166,759 cfs from February1 June 30) was closest to the "Critical" water year of 1994 (Table 2.5), the first year the larval fishes of Suisun Marsh were studied. Our 2001 larval fish catch clearly reflects these low outflow conditions, which likely contributed to increased abundances of prickly sculpin and longfin smelt, as well as other native species more commonly encountered in higher salinity waters downstream of the marsh (i.e. cheekspot goby, Pacific herring, and northern anchovy). The abundance of shimofuri goby and striped bass was also very high in 2001, most likely due to favorable environmental conditions for spawning in the marsh (i.e. shimofuri goby) and survival for both species. These same low outflow conditions (i.e. higher salinity and temperature) likely contributed to the low abundance of species more commonly associated with higher freshwater flow including delta smelt, Sacramento sucker, Sacramento splittail, bigscale logperch and *Pomoxis* sp.

Table 2.1 Data from the Suisun Marsh larval fish survey conducted from February 1, 2001 to June 12, 2001. SPP = Maximum number of species-family categories caught. Temperature, salinity, and secchi are in degrees C, ppt, and cm, respectively.

		Month					
Slough	**Data**	**February**	**March**	**April**	**May**	**June**	**Grand Total**
Cordelia	Average of Temp	9.8	14.3	16.1	20.1	21.0	15.6
	Average of Sal	2.2	1.6	2.3	3.7	4.6	2.5
	Average of Secchi	24.8	16.8	16.7	19.2	25.3	18.9
	Sum of FISH	3336	2777	536	1947	162	8758
	Avg of FISH/M^3	3.5	1.8	0.4	1.3	0.3	1.5
	Total # SPP	5	8	11	9	5	16
Denverton	Average of Temp	9.3	14.7	15.8	20.2	21.5	16.2
	Average of Sal	1.9	1.5	1.2	1.3	2.5	1.6
	Average of Secchi	26.7	19.9	17.3	17.3	23.0	20.1
	Sum of FISH	1400	1571	320	3566	2256	9113
	Avg of FISH/M^3	1.5	0.9	0.2	2.2	3.6	1.5
	Total # SPP	4	4	4	8	5	9
Nurse	Average of Temp	9.2	14.0	15.5	19.7	20.6	15.8
	Average of Sal	1.2	0.7	0.6	1.5	2.9	1.2
	Average of Secchi	28.6	22.7	20.3	23.1	31.5	24.2
	Sum of FISH	337	678	269	2153	1790	5227
	Avg of FISH/M^3	0.2	0.4	0.2	1.3	2.9	0.8
	Total # SPP	3	4	5	12	3	13
Spring Branch	Average of Temp	9.3	14.5	15.7	20.8	20.5	16.3
	Average of Sal	1.9	1.2	1.1	1.5	2.5	1.5
	Average of Secchi	26.2	16.6	18.3	18.2	17.7	19.0
	Sum of FISH	827	1903	477	5106	2209	10522
	Avg of FISH/M^3	0.8	1.2	0.4	3.2	3.7	1.8
	Total # SPP	3	3	5	8	5	11
Suisun	Average of Temp	9.5	14.3	16.3	19.6	20.6	16.0
	Average of Sal	2.1	1.2	1.2	1.4	2.4	1.5
	Average of Secchi	25.0	18.7	19.8	17.5	25.2	20.3
	Sum of FISH	757	920	613	6228	3332	11850
	Avg of FISH/M^3	0.6	0.5	0.5	3.8	5.1	1.8
	Total # SPP	6	3	7	8	2	13
Total Average of Temp		9.42	14.36	15.87	20.07	20.79	16.09
Total Average of Salinity		2	1	1	2	3	2
Total Average of Secchi		20.63	18.96	18.48	19.07	24.32	20.63
Total Sum of Fish		6657	7849	2215	19000	9749	45470
Total Average of Fish / M^3		1.49	0.97	0.34	2.34	3.17	1.49
Total Number of Species		9	11	12	16	8	21

Table 2.2 Families and species captured in five sloughs sampled by the Suisun Marsh larval fish survey in 2001. YFG = yellowfin goby, SG = shimofuri goby, CSG = cheekspot goby, LJM = longjaw mudsucker, SCP = pirckly sculpin, STAG = staghorn sculpin, SB = striped bass, TFS = threadfin shad, HER = Pacific herring, ANCH = anchovy, ISS = inland silverside, JSM = jacksmelt, STBK = threespine stickleback, DS = delta smelt, LFS = longfin smelt, WAK = Wakasagi smelt, CP = carp, ST = Sacramento splittail, SKR = Sacramento sucker, CENT = Centrarchidae (Pomoxis sp.).

	SLOUGH					
	Cordelia	**Denverton**	**Nurse**	**Spring Branch**	**Suisun**	**Total All Sloughs**
YFG	109	0	0	0	1	110
SG	1260	4892	3255	6685	9409	25500
CSG	107	0	0	0	0	107
LJM	1	0	1	0	0	2
SCP	2980	3019	824	2917	1889	11629
STAG	0	0	0	2	1	3
SB	762	906	707	631	306	3313
TFS	0	16	15	11	4	46
HER	206	31	14	5	10	267
ANCH	255	16	21	15	19	326
ISS	3	0	2	8	7	20
JSM	1	0	0	0	0	1
STBK	16	0	0	0	0	16
DS	1	10	17	0	5	33
LFS	3050	220	347	238	192	4048
WAK	1	0	1	0	0	2
CP	3	2	22	6	0	33
ST	0	0	1	0	0	1
FHM	0	0	0	0	2	2
SKR	4	0	0	0	0	4
CENT	0	0	0	4	4	8
Total # Individuals	8758	9113	5227	10522	11850	45470
Total # Species	16	9	13	11	13	21

Table 2.3 Families and species captured by the Suisun Marsh larval fish survey by month in 2001. YFG = yellowfin goby, SG = shimofuri goby, CSG = cheekspot goby, LJM = longjaw mudsucker, SCP = prickly sculpin, STAG = staghorn sculpin, SB = striped bass, TFS = threadfin shad, HER = Pacific herring, ISS = inland silverside, JACK = jacksmelt, STBK = threespine stickleback, DS = delta smelt, LFS = longfin smelt, WAK = wakasagi, CP = carp, ST = Sacramento splittail, FHM = fathead minnow, SKR = Sacramento sucker, CENT = Centrarchidae - Pomoxis sp., BLP = bigscale logperch, . Sloughs were sampled weekly from February 1, 2001 through June 12, 2001.

	MONTH					
	February	March	April	May	June	Total All Months
Sum of YFG	11	51	48	0	0	110
Sum of SG	0	4	430	15389	9677	25500
Sum of CSG	0	1	4	99	3	107
Sum of LJM	0	0	1	1	0	2
Sum of SCP	5182	5136	1085	225	2	11629
Sum of STAG	1	2	0	0	0	3
Sum of SB	2	0	422	2883	5	3313
Sum of TFS	0	0	0	22	24	46
Sum of HER	252	15	0	0	0	267
Sum of ANCH	1	0	2	291	32	326
Sum of ISS	0	0	1	15	4	20
Sum of JACK	0	0	0	0	1	1
Sum of STBK	11	1	0	4	0	16
Sum of DS	2	4	3	24	0	33
Sum of LFS	1196	2630	214	7	0	4048
Sum of WAK	0	0	0	2	0	2
Sum of CP	0	1	4	28	0	33
Sum of ST	0	0	0	1	0	1
Sum of FHM	0	0	0	2	0	2
Sum of SKR	0	4	0	0	0	4
Sum of CENT	0	0	1	7	0	8
Total # of Indiv	6657	7849	2215	19000	9749	45470
Total # of SP	9	11	12	16	8	21

Table 2.4 Delta smelt (DS/M^3), longfin smelt (LFS/M^3), and splittail (ST/M^3) densities per cubic meter sampled by the Suisun Marsh larval fish survey in 2001. Sloughs were sampled weekly from February 1, 2001 through June 12, 2001. Temperature, salinity, and secchi are in degrees Centigrade, parts per thousand, and cm, respectively. In all cases, minimum densities were 0.

		MONTH					
SLOUGH		**February**	**March**	**April**	**May**	**June**	**Grand Total**
Cordelia	Average of DS/M^3	0.000	0.000	0.001	0.000	0.000	0.000
	Max of DS/M^3	0.000	0.000	0.009	0.000	0.000	0.009
	Average of LFS/M^3	0.787	1.388	0.110	0.001	0.000	0.487
	Max of LFS/M^3	1.835	5.219	0.360	0.019	0.000	5.219
	Average of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
	Max of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
Denverton	Average of DS/M^3	0.000	0.001	0.000	0.006	0.000	0.002
	Max of DS/M^3	0.000	0.009	0.000	0.036	0.000	0.036
	Average of LFS/M^3	0.089	0.079	0.002	0.001	0.000	0.034
	Max of LFS/M^3	0.273	0.315	0.010	0.018	0.000	0.315
	Average of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
	Max of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
Nurse	Average of DS/M^3	0.000	0.001	0.001	0.009	0.000	0.002
	Max of DS/M^3	0.000	0.008	0.010	0.101	0.000	0.101
	Average of LFS/M^3	0.151	0.095	0.018	0.002	0.000	0.050
	Max of LFS/M^3	0.569	0.233	0.090	0.010	0.000	0.569
	Average of ST/M^3	0.000	0.000	0.000	0.001	0.000	0.000
	Max of ST/M^3	0.000	0.000	0.000	0.010	0.000	0.010
Spring Branch	Average of DS/M^3	0.000	0.000	0.000	0.000	0.000	0.000
	Max of DS/M^3	0.000	0.000	0.000	0.000	0.000	0.000
	Average of LFS/M^3	0.144	0.049	0.017	0.000	0.000	0.039
	Max of LFS/M^3	0.745	0.227	0.052	0.000	0.000	0.745
	Average of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
	Max of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
Suisun	Average of DS/M^3	0.002	0.001	0.001	0.000	0.000	0.001
	Max of DS/M^3	0.017	0.010	0.009	0.000	0.000	0.017
	Average of LFS/M^3	0.077	0.050	0.020	0.000	0.000	0.028
	Max of LFS/M^3	0.244	0.128	0.077	0.000	0.000	0.244
	Average of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
	Max of ST/M^3	0.000	0.000	0.000	0.000	0.000	0.000
Total Average of DS/M^3		0.000	0.002	0.003	0.000	0.001	0.001
Total Max of DS/M^3		0.009	0.036	0.101	0.000	0.017	0.101
Total Average of LFS/M^3		0.513	0.036	0.053	0.039	0.030	0.134
Total Max of LFS/M^3		5.219	0.315	0.569	0.745	0.244	5.219
Total Average of ST/M^3		0.000	0.000	0.000	0.000	0.000	0.000
Total Max of ST/M^3		0.000	0.000	0.010	0.000	0.000	0.010

Table 2.5 Monthly total Net Delta Outflow (cfs), number of fish, and number of samples from the Suisun Marsh larval fish survey from 1994-2001. Outflow data and dry, wet, and normal water year designations were provided by the Califonia Department of Water Resources.

		February	March	April	May	June	Total
1994	**Outflow**	575459	329991	244689	246295	118732	1515166
Critical	**Fish**			4450	8786	44331	57567
	Samples			42	60	44	146
	# Fish / Sample			106	146	1008	394
1995	**Outflow**	2037777	6220911	2725494	3040257	1405074	15429513
Wet	**Fish**	1141	6286	6771	16737	13775	44710
	Samples	10	75	60	60	45	250
	# Fish / Sample	114	84	113	279	306	179
1996	**Outflow**	3680341	2760590	1261687	1428760	462661	9594039
Wet	**Fish**	2518	6492	4717	10317	2376	26420
	Samples	60	75	57	66	15	273
	# Fish / Sample	42	87	83	156	158	97
1997	**Outflow**	3325676	1042711	425284	382311	249328	5425310
Wet	**Fish**	3896	4961	2702	35505	10474	57538
	Samples	60	60	60	75	15	270
	# Fish / Sample	65	83	45	473	698	213
1998	**Outflow**	6466792	3230457	2651428	2102350	2152735	16603762
Wet	**Fish**	181	5038	2736	8755	3035	19745
	Samples	6	60	60	39	30	195
	# Fish / Sample	30	84	46	224	101	101
1999	**Outflow**	2766464	2141511	1064838	687096	413782	7073691
Wet	**Fish**	4675	9274	5760	*405		*20114
	Samples	60	60	60	*12		*192
	# Fish / Sample	78	155	96	*34		*105
2000	**Outflow**	2730402	2721645	813100	687628	269150	7221925
Above	**Fish**	7798	6347	3248	7128	3917	28439
Normal	**Samples**	58	75	60	60	30	283
	# Fish / Sample	134	85	54	119	131	100
2001	**Outflow**	548945	725948	366814	299358	225694	2166759
Dry	**Fish**	6657+	7849	2215	19000	9749	45470
	Samples	45+	73	60	75	30	283
	# Fish / Sample	147.93+	108	37	253	325	161

*In 1999, larval fish sampling was stopped after May 6 due to delta smelt take restrictions. Larval fish totals and the grand total will reflect this early end to the sampling season. +February 2001 totals are based upon three weeks of samples (no samples were collected in the second week of February).

Table 2.6 Species of concern captured during the Suisun Marsh larval fish survey between 1994 and 2001. The abundance of Splittail in 1994 was unavailable. It is important to note that sampling effort and number of months sampled varied between sampling years.

Year	Longfin smelt	Delta smelt	Splittail	# Of Samples
1994	19	13		146
1995	22	77	61	250
1996	271	954	6	273
1997	1273	20	0	270
1998	17	53	19	195
1999	250	99	0	192
2000	1700	122	7	283
2001	4048	33	1	283

Figures

Figure 2.1. Suisun Marsh larval fish study site map.

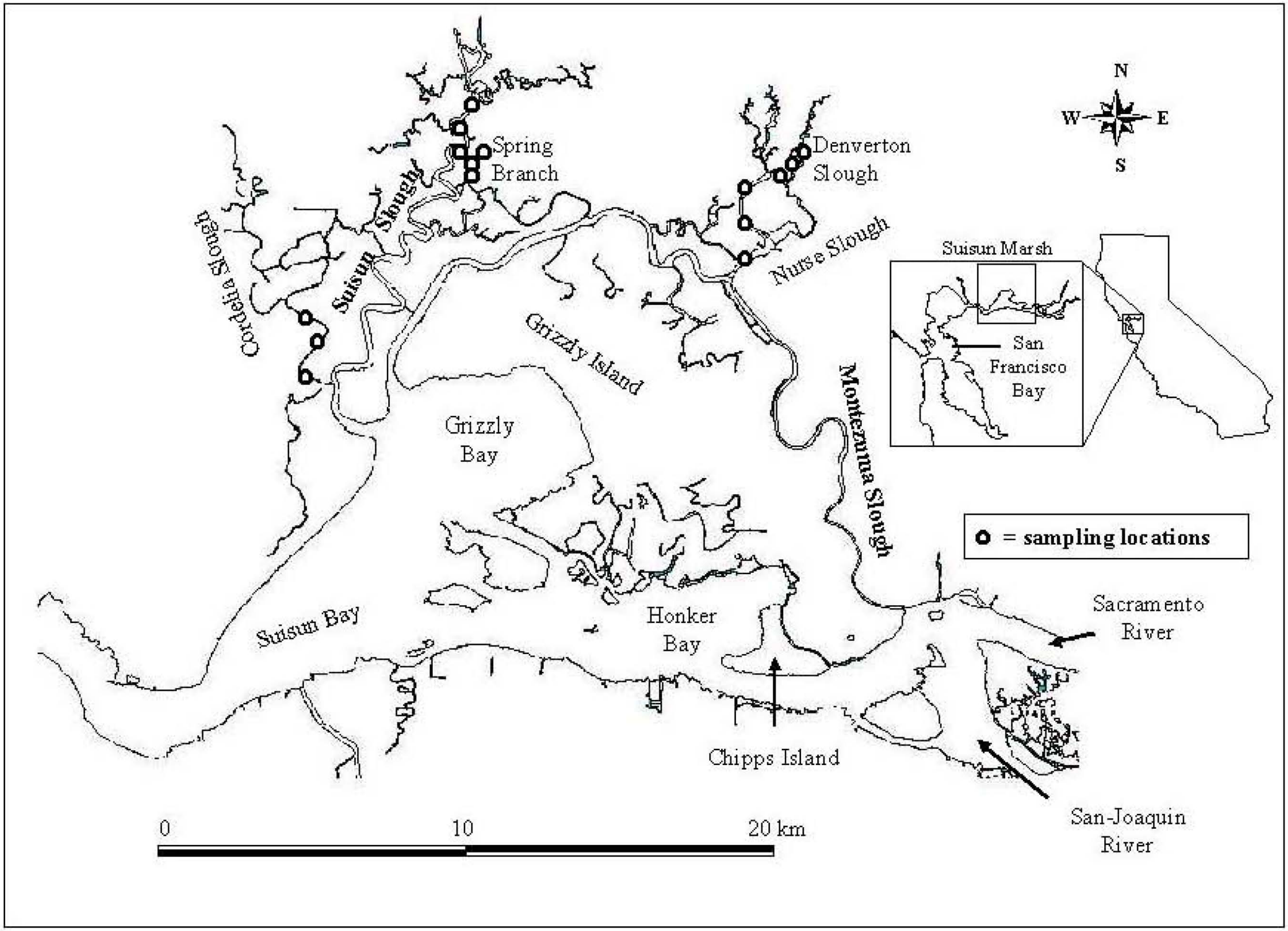
Figure 2.2. Number of species, total larval fish, number of gobies, and sculpins caught by month. Number of species refers to the total number of species caught during the month indicated.

Figure 2.3. Number of larval fish and total species captured by slough.

Figure 2.4. Species of concern by month.

Figure 2.5. Species of concern by slough.

Figure 2.6. Species of concern by year. Number of samples and months sampled varied depending upon the year. See Table 2.5 for a description of number of samples collected per month in each of the sampled years.



N
W
E
S
Spring
Branch
Denverton
Slough
Cordelia Slough
Suisun Slough
Nurse Slough
Suisun Marsh
Grizzly Island
San
Francisco
Bay
Montezuma Slough
Grizzly
Bay
= sampling locations
Sacramento
River
Suisun Bay
Honker
Bay
Chipps Island
San-Joaquin
River
0
10
20 km

Figure 2.1

Number of species, total larval fish, shimofuri gobies, and sculpins by month (2001)

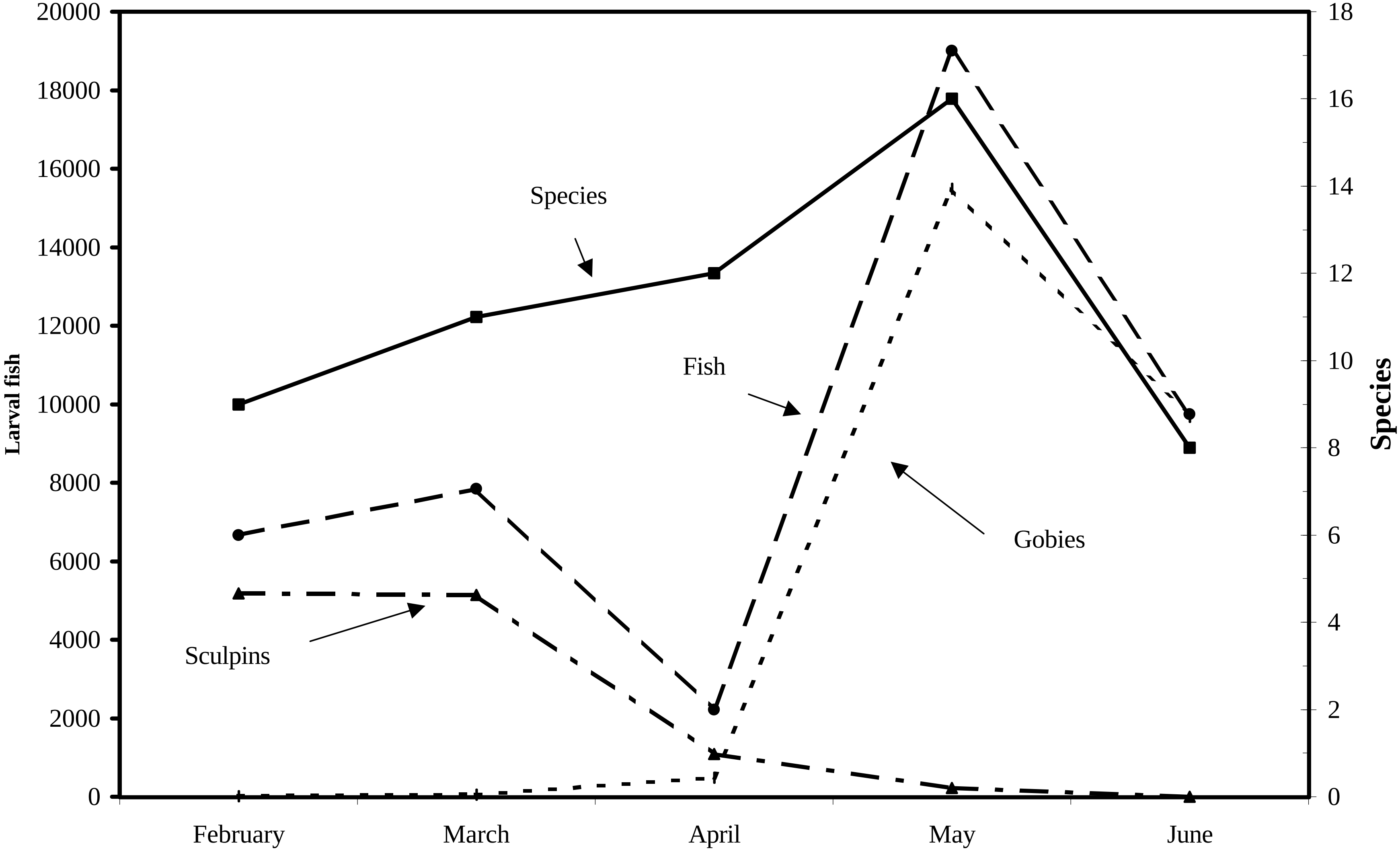


Figure 2.2

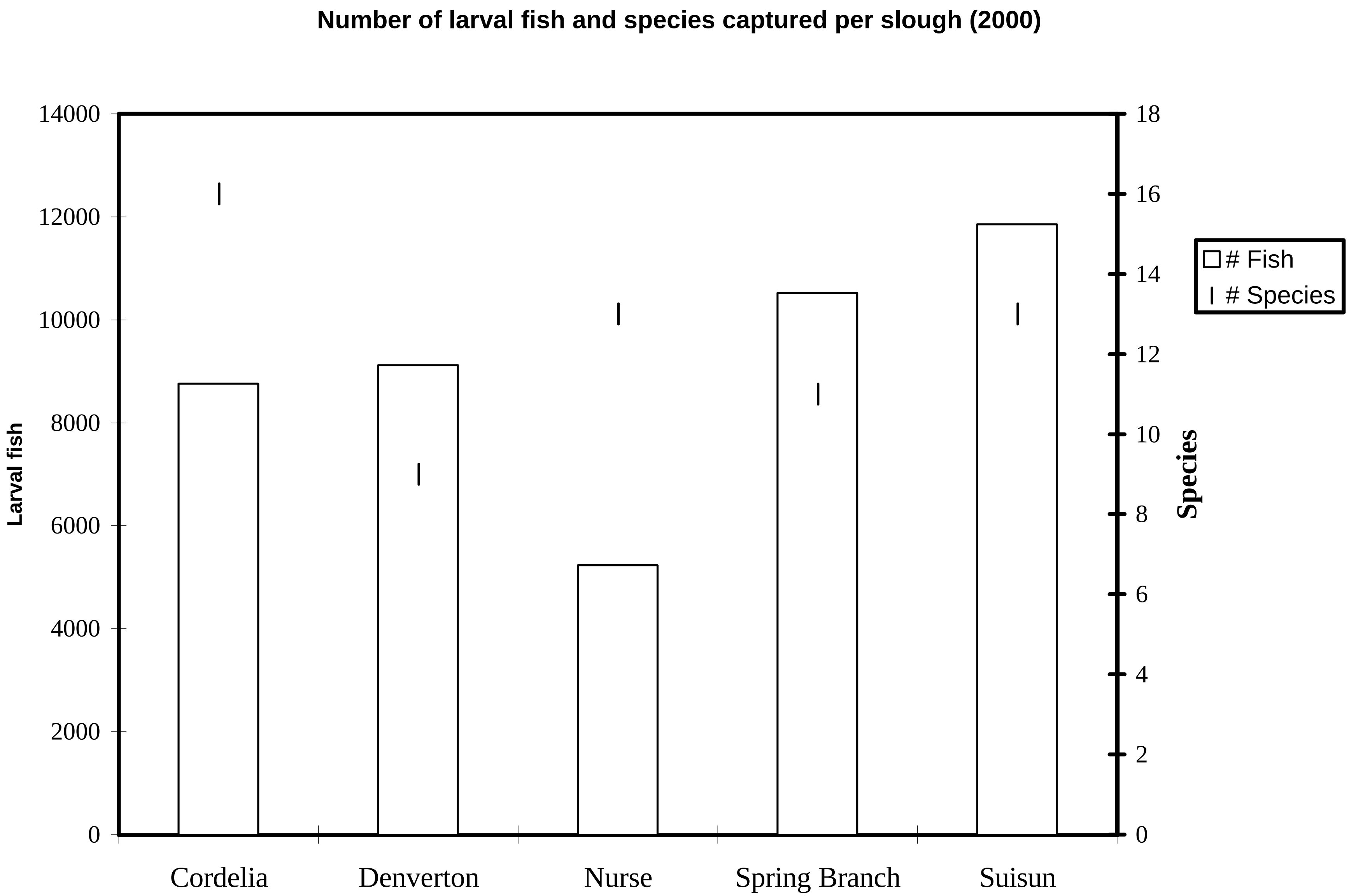

Number of larval fish and species captured per slough (2000)
Larval fish
14000
12000
10000
8000
6000
4000
2000
0
Species
18
16
14
12
10
8
6
4
2
0
Fish
Species
Cordelia
Denverton
Nurse
Spring Branch
Suisun

Figure 2.3

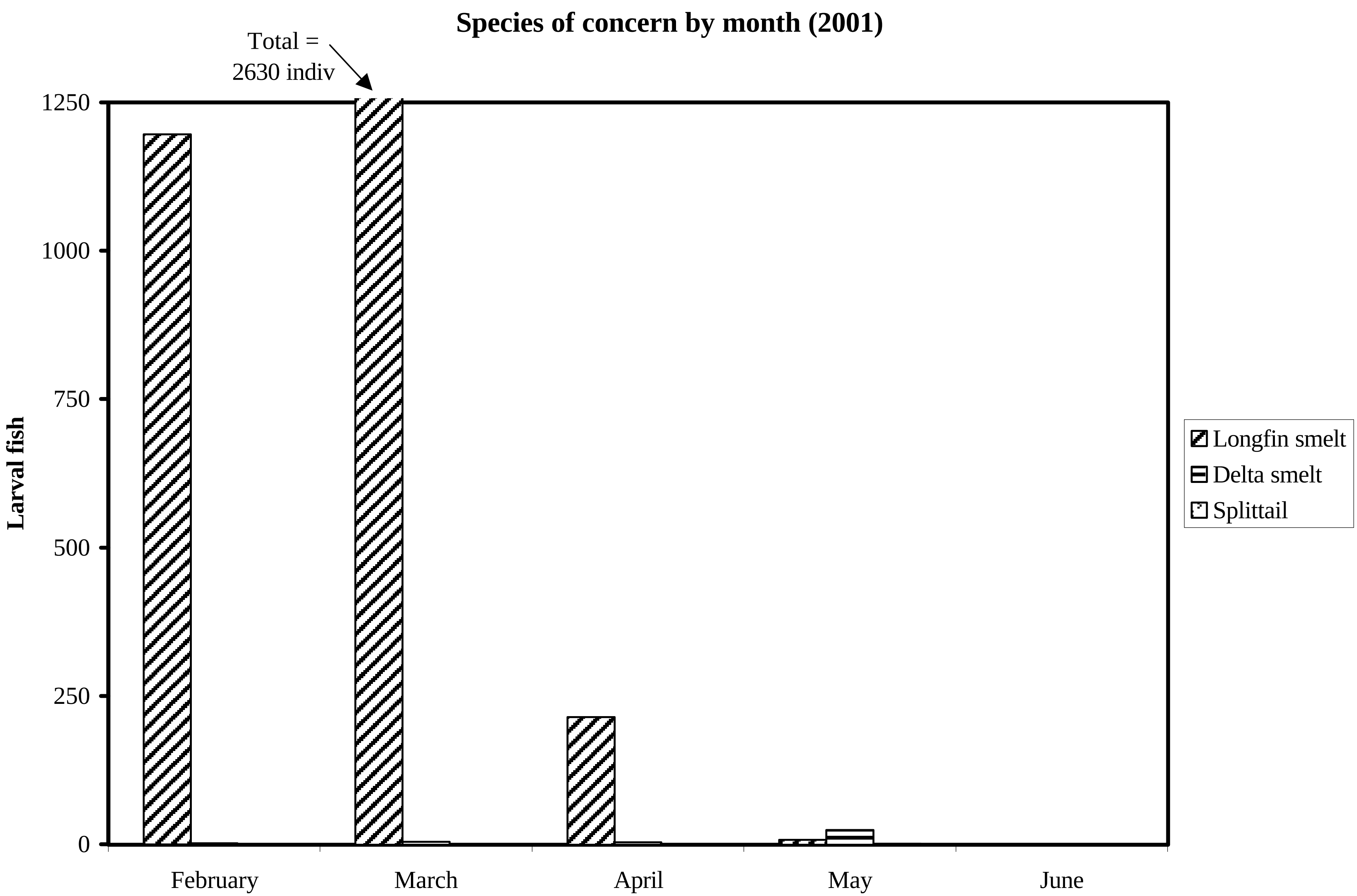
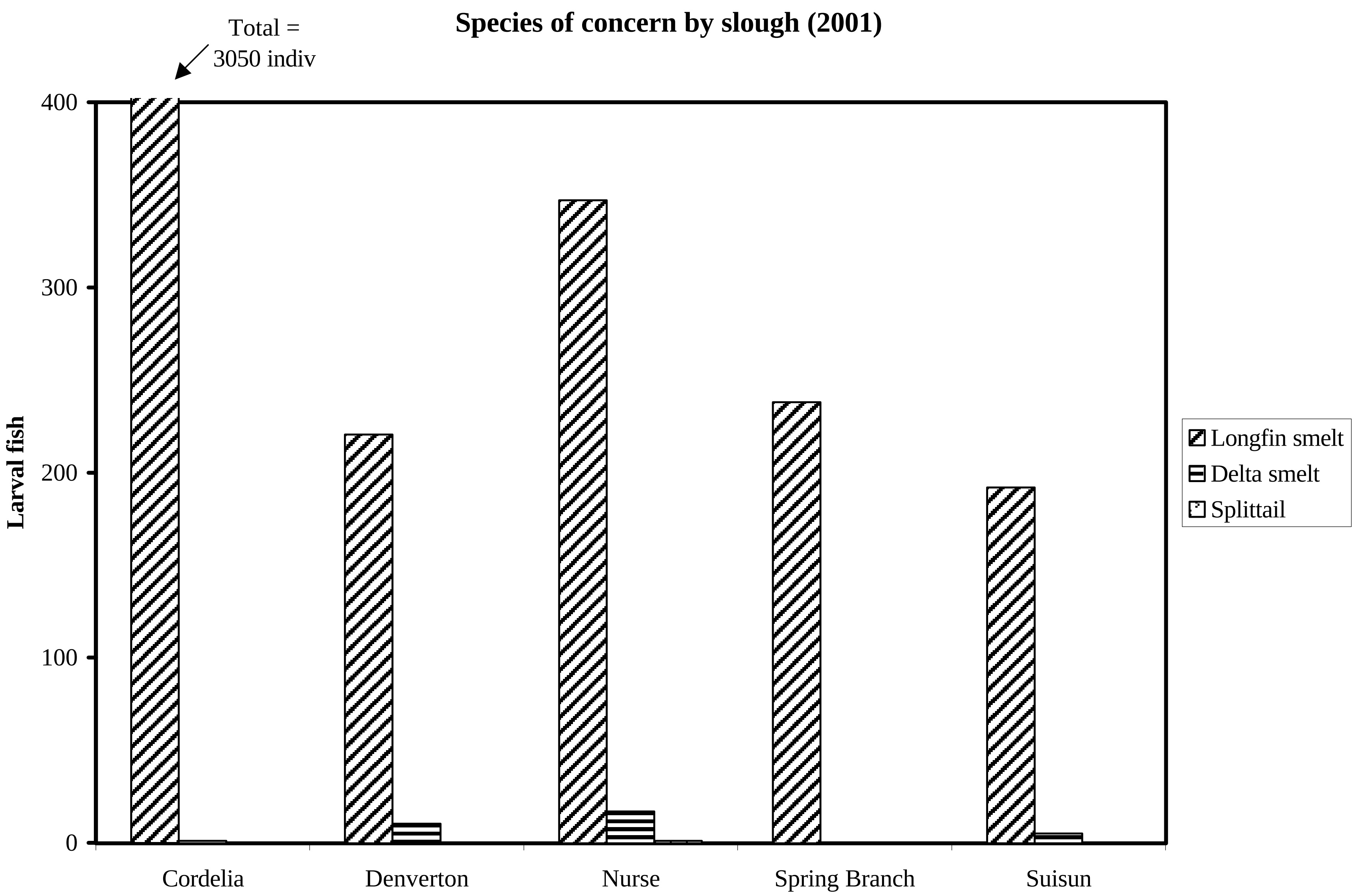

Species of concern by month (2001)
Total =
2630 indiv
1250
1000
750
500
250
0
Larval fish
February
March
April
May
June
Longfin smelt
Delta smelt
Splittail

Figure 2.4



Species of concern by slough (2001)
Total =
3050 indiv
400
300
200
100
0
Larval fish
Cordelia
Denverton
Nurse
Spring Branch
Suisun
Longfin smelt
Delta smelt
Splittail

Figure 2.5

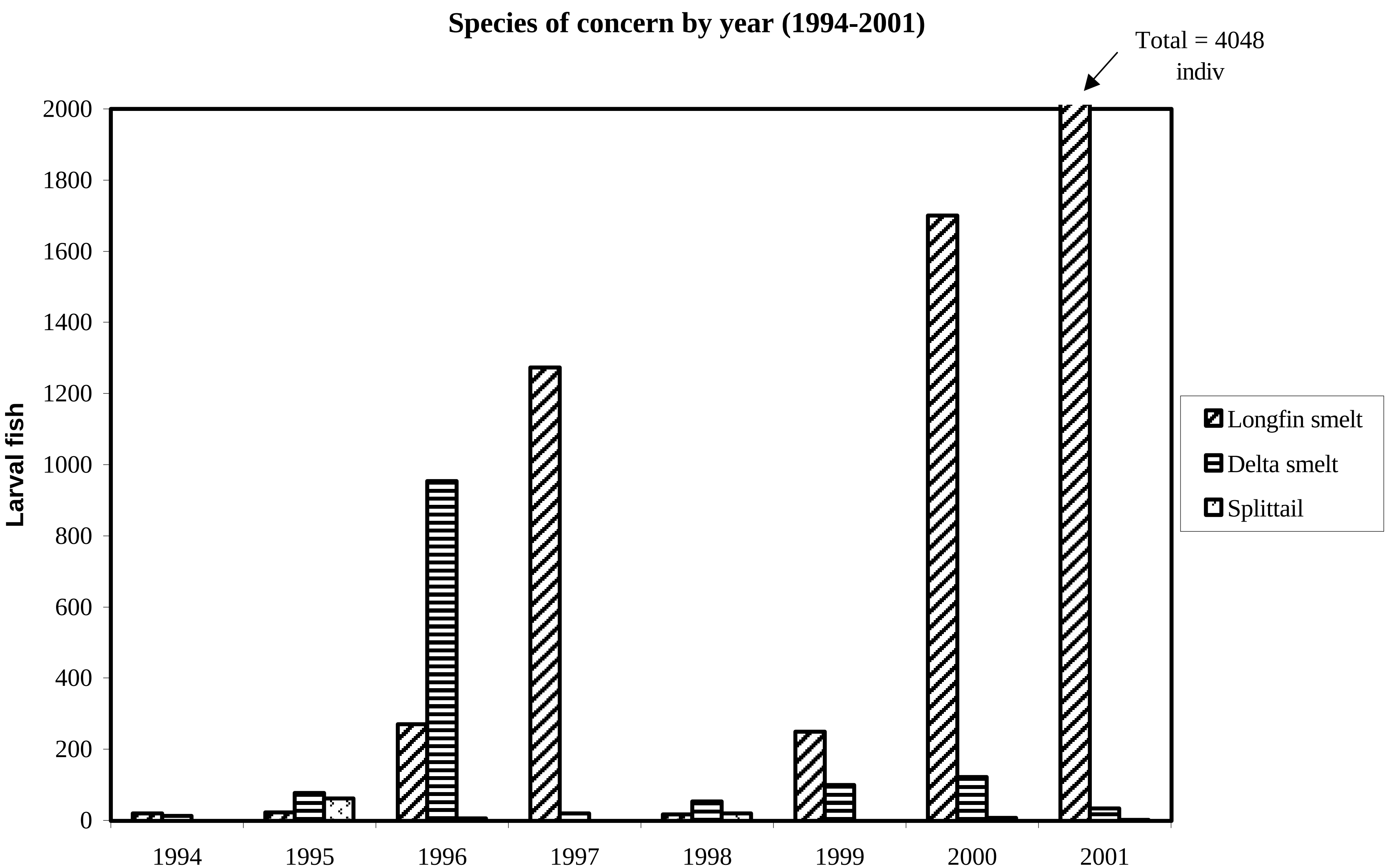

Species of concern by year (1994-2001)
Total = 4048 indiv
Larval fish
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1994
1995
1996
1997
1998
1999
2000
2001
Longfin smelt
Delta smelt
Splittail

Figure 2.6

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Appendix Mean catch per trawl for several categories of fish and invertebrate species captured in Suisun Marsh.

yr	trawls	intros	natives	SB	YFG	SG	ST	DS	LFS	TP	SCP	SKR	STAG	Cra	Pal
		Figure 1.5		Fig. 1.6	Figure 1.7		Fig 1.8	Figure 1.9		Fig. 1.10	Figure 1.11			Fig. 1.13	
1980	483	18.03	31.36	13.40	2.40	0.00	7.69	0.35	6.72	3.98	3.25	1.13	0.73	no data	no data
1981	407	26.21	31.94	22.63	0.57	0.00	4.54	0.57	2.34	5.84	1.60	1.50	0.90	44.54	11.95
1982	266	14.12	23.64	12.23	0.74	0.00	4.31	0.12	6.39	5.86	2.40	0.65	0.12	40.41	8.16
1983	218	19.45	14.55	18.17	0.11	0.00	3.25	0.05	1.28	0.80	5.39	0.84	0.04	3.25	3.08
1984	157	23.52	7.72	14.57	6.39	0.00	1.22	0.00	3.52	0.69	0.81	0.63	0.25	16.74	2.99
1985	210	14.52	6.10	10.70	0.98	0.01	0.72	0.00	0.77	2.38	0.35	0.67	0.48	6.27	8.09
1986	197	18.76	11.05	13.68	2.84	0.00	3.38	0.00	0.52	3.06	1.91	0.51	0.27	40.03	4.92
1987	206	9.74	13.00	6.86	1.35	0.57	2.15	0.00	0.53	6.20	0.25	0.33	0.09	53.50	14.58
1988	216	8.09	9.53	5.70	0.52	1.31	0.75	0.00	0.90	5.90	0.53	0.24	0.45	27.33	5.09
1989	152	18.92	5.14	7.69	2.42	8.24	0.71	0.01	0.86	1.56	0.27	0.14	0.50	50.45	10.12
1990	188	7.64	4.11	2.04	0.77	4.36	0.43	0.01	1.29	0.98	0.06	0.11	0.28	25.96	7.51
1991	206	11.67	7.04	7.68	0.17	3.38	0.96	0.02	0.10	0.92	0.85	0.03	0.82	42.87	4.30
1992	203	16.96	3.42	13.26	1.66	1.74	0.66	0.01	0.01	1.03	0.67	0.03	0.09	10.53	2.60
1993	202	22.67	2.56	5.00	16.69	0.58	0.31	0.03	0.01	0.48	1.20	0.09	0.07	16.76	1.50
1994	228	6.97	1.89	3.47	0.76	2.34	0.22	0.07	0.03	0.69	0.30	0.08	0.08	20.63	0.64
1995	245	16.25	7.27	6.04	8.88	0.48	1.06	0.01	0.33	0.38	2.75	0.14	1.11	48.57	1.52
1996	252	8.77	6.10	6.02	0.99	0.19	1.74	0.05	0.03	0.34	2.08	0.25	0.20	37.92	0.28
1997	252	18.90	6.44	12.09	0.72	4.77	0.90	0.00	0.02	1.00	2.15	0.23	0.19	136.25	3.42
1998	216	7.35	10.56	3.24	1.31	0.62	1.23	0.01	0.10	0.73	1.84	0.31	0.05	23.90	2.65
1999	251	18.30	7.79	8.21	6.34	1.53	1.55	0.10	4.51	0.16	0.61	0.20	0.14	16.89	0.12
2000	252	27.79	8.91	11.28	13.60	0.56	2.20	0.06	1.56	0.22	1.24	0.21	0.31	30.63	0.95
2001	250	23.36	8.93	16.98	2.05	2.64	4.74	0.13	1.16	1.78	0.07	0.18	0.18	33.15	15.98